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Aerial Spray Evaluation
Pine Butterfly Test
Bitterroot National Forest, Montana
1973

DATA REPORT

BY

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JANUARY 1975

U. S. Army Dugway Proving Ground
Dugway, Utah 84022

U. S. Department of Agriculture
Forest Service, Region 1
Division of State and Private Forestry
and
Missoula Equipment Development Center
Missoula, Montana 59801

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The US Department of Agriculture, Forest Service, conducted a pilot test in the Bitterroot National Forest, Montana, during June 1973, supported by the US Army Dugway Proving Ground, Dugway, Utah. The pilot test consisted of helicopter spraying twelve 40-acre plots. Each plot had a high population level of pine butterfly {Neophasia menapia (Felder and Felder)}, a defoliator

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US Army support included meteorological forecasting, meteorological monitoring at each plot, spray deposition sampling, deposition sampler assessment, pretest prediction modeling of spray behavior, and tracking during helicopter swathing.

The report presents results and recommendations on recoveries of spray droplets, spray penetration plots of the forest canopy, and discussions on droplet behavior. A separate publication by the Forest Service, Region 1, reports on the biological aspects of this test.

19. Key Words (Continued)

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ABSTRACT

The US Department of Agriculture, Forest Service, conducted a pilot test in the Bitterroot National Forest, Montana, during June 1973, supported by the US Army Dugway Proving Ground, Dugway, Utah. The pilot test consisted of helicopter spraying twelve 40-acre plots. Each plot had a high population level of pine butterfly {*Neophasia menapia* (Felder and Felder)}, a defoliator of the ponderosa pine. Six plots were sprayed with the insecticide Zectran, and six with the microorganism, *Bacillus thuringiensis*.

US Army support included meteorological forecasting, meteorological monitoring at each plot, spray deposition sampling, deposition sampler assessment, pretest prediction modeling of spray behavior, and tracking during helicopter swathing.

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FOREWORD

This test was conducted by the US Department of Agriculture Forest Service with support from the US Army Dugway Proving Ground, Dugway, Utah, as a continuation of cooperative agreements on transfer of technology between the two agencies. Costs for the support were provided by the Forest Service under a supplemental agreement to the memorandum of understanding between the US Army Materiel Command and the US Forest Service.

The US Forest Service, Region 1, Division of State and Private Forestry, had overall responsibility for the planning and execution of the test. The US Forest Service, Missoula Equipment Development Center (MEDC), sponsored and coordinated the US Army support. Results of several satellite studies conducted by MEDC during the pilot test are also presented in this report.

Acknowledgements are given to Mr. Kaye Johnson of Los Alamos Scientific Laboratory, Los Alamos, New Mexico, for the counting of droplets on 8,000 deposition cards; to Mr. Don Weatherhead, MEDC, for preparation of test plot sketches and forest descriptions; to Mr. Douglas Boyle, Dugway, Utah, for staff coordination which contributed to the success of the cooperative agreement; to Mr. Paul Carlson, Dugway, Utah, for providing meteorological support; and to Dr H.E. Cramer and K.E. Dumbauld, H.E. Cramer Company, for pretest modeling of downwind drift of the helicopter spray materials.

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SECTION 1. SUMMARY

1.1 INTRODUCTION AND BACKGROUND

During the past few years, the pine butterfly, *Neophasia menapia* (Felder and Felder) has become epidemic over approximately 40,000 acres of private, state, and national-forest land in the Bitterroot Valley, Montana.(1) To investigate insecticide agents for control of the pine butterfly, the US Forest Service (USFS) conducted a pilot test in the Bitterroot National Forest.(2,3) In 1973, the forest had a high population of the butterfly with evidence of moderate to severe damage to the ponderosa stands from previous years' infestations. These circumstances provided an ideal situation for the evaluation of two candidate control agents - Zectran, a nonpersistent insecticide; and the bacterium, *Bacillus thuringiensis* (*Bt*.) which attacks the butterfly in the larval stage.

The test provided an opportunity for the USFS Missoula Equipment Development Center (MEDC) to investigate methods for sampling liquid spray releases from helicopters, and to evaluate items of equipment and various techniques for aerial dispersion of insecticides.

Since 1971 the US Army Dugway Proving Ground has been providing assistance to the USFS on forest insect control projects.(4) The scope of support for this test was to provide scientific and technical personnel to assist in meteorological measurements and analyses, test design, spray droplet sampling, sampler assessment, data analyses, and mathematical modeling of insecticide spray behavior.

In 1974, the USFS published a report[3] on the effectiveness of the two materials (Zectran and Bt.) for control of the pine butterfly. This report should be considered as a supplement to the USFS report. Analyses of specific areas of interest can be made based on the data presented herein. A discussion is presented for each task performed.

Fluorescent particles (FP) were added to the spray formulation on three of the Bt. trials, and deposition samples were obtained. The FP data will be analyzed in the near future.

It is beyond the scope of this study to anticipate investigative requirements relating to the planning and conduct of future spray trials which may become apparent during the review of the data presented in this report.

1.2 OBJECTIVE

The objective of this test was to evaluate a nonpersistent insecticide and a bacterium for control of the pine butterfly (*N. menapia*) within a ponderosa pine forest.

1.3 TASK OBJECTIVES

Six tasks were addressed to satisfy the objective:

a. *Task 1*. To obtain meteorological data at each test plot during conduct of spray operations.

b. *Task 2*. To investigate canopy penetration of chemical and biological insecticidal sprays released over a ponderosa pine forest.

c. *Task 3*. To determine mass distribution and volume median diameter (vmd) of the spray.

d. Task 4. To evaluate the optimum method for sampling spray deposition for both operational control projects, pilot tests, and field experiments.

e. Task 5. To compare model predictions of spray deposition at ground level in forest clearings with actual recoveries obtained on field trials at ground level in forest clearings.

f. Task 6. To monitor the accuracy of helicopter swathing.

1.4 SCOPE

Twelve trials were conducted in the Bitterroot National Forest, Montana, during June 1973. Each trial consisted of helicopter spraying by the swath method over a 40-acre plot. Three plots were sprayed during morning hours (consistent with the operational capability of the helicopter) to provide three trial replicates per test day. Tables 1 and 2 present a summary of the test scope.

1.5 SITE AND TEST PLOT DESCRIPTION

The Bitterroot National Forest is located south of Missoula, Montana, and north of Darby, Montana, (Figure 1), in the Bitterroot Valley. All trial plots, with the exception of the Sawdust Gulch plot, were located west of the Bitterroot River with generally easterly exposures.

Photographs of selected individual sample trees are presented in Appendix B. Plot descriptions are given below.

a. Plot 1 - Mill Creek. The Mill Creek plot is located in the NE1/4 sec. 4, T. 6 N., R. 21 W. at an elevation of 4,000 feet.

Table 1. Test Scope for Zectran Trials

Trial	Test Date (1973)	Spray Time (MDT)	Spray Site and Sequence	Zectran per Gallon (lb)	Gallons per Acre
Z-1-1	4 Jun	0600-0612	Mill Creek	0.15	1
Z-1-2	4 Jun	0630-0645	North Bear	0.15	1
Z-1-3	4 Jun	0725-0740	Smith Creek	0.15	1
Z-2-4	5 Jun	0620-0638	Canyon Creek	0.30	1
Z-2-5	5 Jun	0648-0705	Lower Blodgett	0.30	1
Z-2-6	5 Jun	0726-0742	Big Creek	0.30	1

Table 2. Test Scope for _Bacillus_ _thuringiensis_ Trials

Trial	Test Date (1973)	Spray Time (MDT)	Spray Site and Sequence	Bacillus per Gallon (lb)	Gallons per Acre
B-1-1	19 Jun	0618-0632	Gash Creek	0.25	2
B-1-2	19 Jun	0703-0715	East Sweeney	0.25	2
B-1-3	19 Jun	0805-0818	West Sweeney	0.25	2
B-2-4	20 Jun	0608-0630	Sawdust Gulch	0.50	2
B-2-5	20 Jun	0655-0708	Upper Blodgett	0.50	2
B-2-6	20 Jun	0723-0737	South Bear	0.50	2

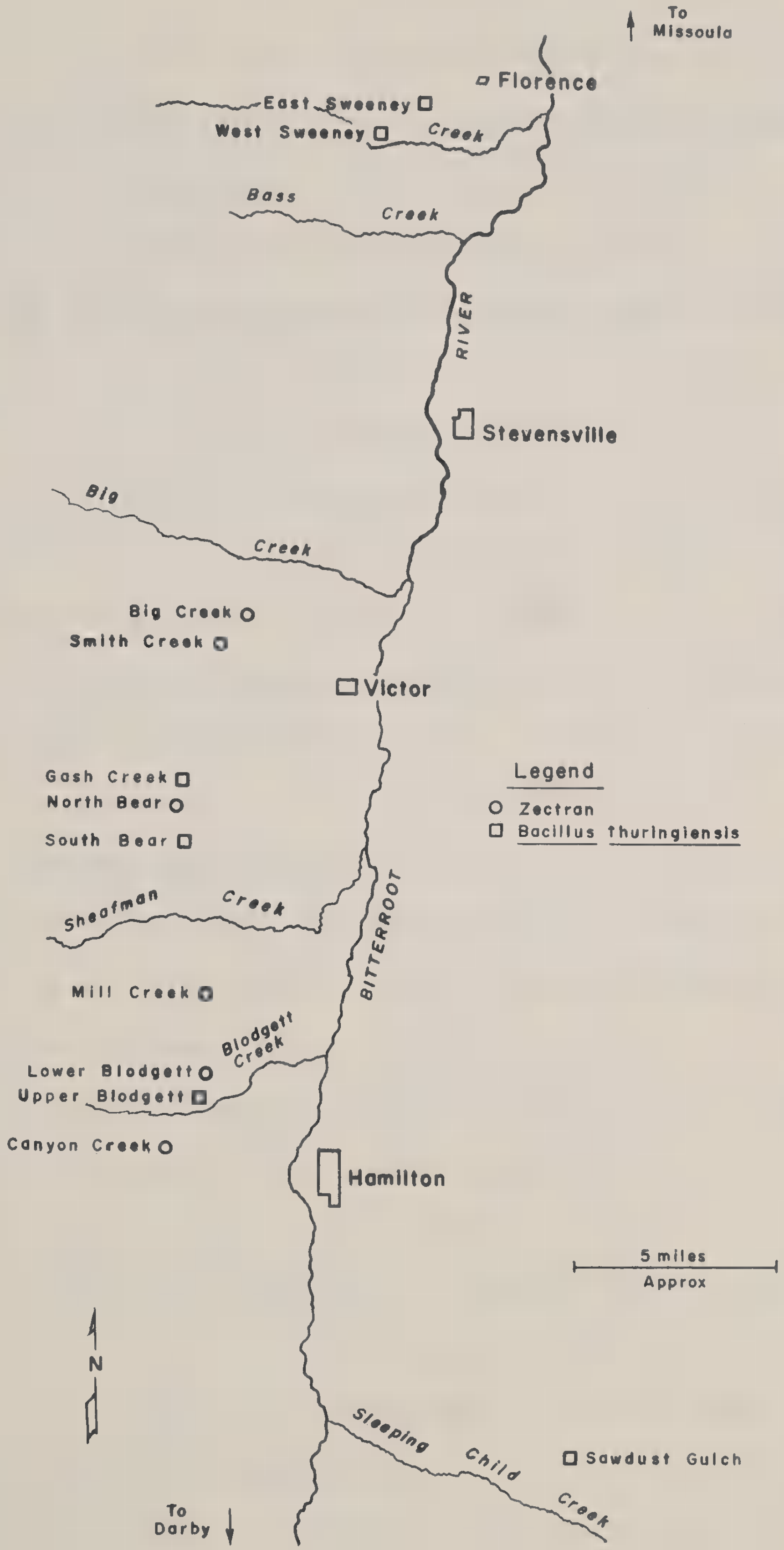


Figure 1. Site Diagram - Bitterroot Valley, Montana

Average slope is approximately 8 percent with an east aspect. The habitat type is Douglas-fir/snowberry. About 80 percent of the trees are ponderosa pine; the remainder are Douglas-fir. Both species are about 60 years old. There are approximately 200 to 300 trees per acre with an average canopy height of 60 to 80 feet and crown width of approximately 16 feet.

b. Plot 2 - North Bear Creek. The Bear Creek plot is located in the S1/2 sec. 9, T. 7 N., R. 21 W. at an elevation of 4,000 feet. The plot is relatively flat with a few short slopes up to 30 percent in the northwest corner of the plot. Soils in the area are derived from granite and are relatively shallow and rocky. Several areas within the plot contain large boulders. The area was logged 30 to 40 years ago. Recently (within 2 years), the larger 50-year-old ponderosa pine were harvested with no subsequent slash disposal. Also, the area has been used for grazing cattle. The habitat type is Douglas-fir/kinnikinnick. Ponderosa pine comprises approximately 80 percent of the stand and is a seral species. Douglas-fir is climax and comprises the remainder of the stand except for a few scattered junipers. The majority of the stand is 50 to 60 years old with some reproduction in younger age classes. There are approximately 200 to 300 trees per acre including saplings and seedlings. However, there are openings where few trees are present and where small thickets have developed containing up to 600 to 700 trees per acre. Average height of the main canopy is 40 to 50 feet with a few scattered dominants reaching 60 feet. Average crown widths are approximately 8 feet for ponderosa pine and 10 feet for Douglas-fir.

c. Plot 3 - Smith Creek. The Smith Creek plot is located in the SW1/4 sec. 22, T. 8 N., R. 21 W. at an elevation of 4,600 feet. Average slope is approximately 28 percent with a southeast aspect. Soils are granitic. The area was logged 50 plus years ago, and again about 10 years ago. Habitat type is Douglas-fir/snowberry. The stand is composed of approximately 74 percent ponderosa pine and 26 percent Douglas-fir. Age of the main crown class is approximately 40 years with a few scattered old growth (120-plus years) trees. There are approximately 130 trees per acre. Average height of the main canopy is 67 feet for the pine and 42 feet for the Douglas-fir. The scattered old growth is approximately 100 feet tall. Average crown width is approximately 18 feet for both species.

d. Plot 4 - Canyon Creek. The Canyon plot is located in the SE1/4 sec. 20, T. 6 N., R. 21 W. at an elevation of 5,000 feet. This plot is located on a steep southeast aspect with slopes ranging from 40 to 70 percent. An old growth (250-plus years) ponderosa pine stand of approximately 20 trees per acre overtops a 60-year-old stand of ponderosa pine and Douglas-fir. There are approximately 150 to 250 trees per acre. The old-growth trees are nearly dead from defoliation by the pine butterfly. Soils are granitic and very shallow. The average height of the older trees is approximately 90 feet; the younger trees are about 60 feet. Average crown width of the 60-year-old trees is about 16 feet.

e. <u>Plot 5 - Lower Blodgett Creek</u>. The Lower Blodgett plot is located in the NE1/4NE1/4 sec. 16, T. 6 N., R. 21 W. at an elevation of 4,140 feet. The plot has an average slope of 12 percent and a generally east aspect. The habitat type is Douglas-fir/snowberry. Most of the stand (approximately 80 percent) is composed of ponderosa pine approximately 60 years old with a few older trees 150-plus years. There are about 500 to 600 trees per acre. The main canopy is about 70 feet with a few scattered older trees reaching 130 feet. Average crown width is approximately 12 to 14 feet.

f. <u>Plot 6 - Big Creek</u>. The Big Creek plot is located in the NE1/4 sec. 22, T. 8 N., R. 21 W. at an elevation of 4,600 feet. Average slope is approximately 25 percent with a south aspect. Soils are granitic. The area has been logged 50-plus years ago and again about 10 years ago. In addition a few trees have been pruned with some thinning. Habitat type is Douglas-fir/snowberry. Most of the stand consists of 50-year-old ponderosa pine. Much of the Douglas-fir has either been logged or thinned from the stand. There are approximately 120 trees per acre. There are a few scattered groups of ponderosa pine 80 to 120 years old reaching a height of 110 feet. However, the main canopy is about 56 feet. Average crown width is approximately 14 feet.

g. <u>Plot 7 - Gash Creek</u>. The Gash Creek plot is located in the NW1/4 sec. 9, T. 7 N., R. 21 W. on the lower third of a broad, south-facing ridge composed of granitic soils with a few rock outcrops. The average slope is approximately 25 percent. The average elevation is 4,300 feet above sea level. The area has been logged at least twice;

first approximately 40 years ago, and recently, about 10 years ago. In addition, the site has been heavily grazed by cattle. The habitat type is Douglas-fir/snowberry in the bunchgrass phase. Ponderosa pine is the major seral species, comprising 60 to 70 percent of the stand. Douglas-fir is the major climax species. No other species are present. All age classes of both species are present from seedlings, saplings, to trees. Trees are in the 40-50-year age bracket which comprises the dominant and codominant crown classes. Total stocking is approximately 180 trees per acre with a significant portion in the sapling stage. The majority of the area is open. The average height of the larger trees is 50 to 60 feet, with a few trees reaching 70 feet. Average crown width is approximately 14 feet for ponderosa pine and 10 feet for Douglas-fir. Shrubs in the understory are sparse. Spotted knapweed and very short clumps of bunchgrass and some Idaho fescue indicate that the area has been overgrazed. Over most of the plot there is no duff and very little litter, resulting in approximately 70 percent bare soil.

h. Plot 8 - East Sweeney Creek. The East Sweeney plot is located in the SE1/4 sec. 16, T. 10 N., R. 20 W., at an elevation of approximately 3,600 feet. Average slope is about 20 percent with a northeast aspect. Soils are granitic. The area was logged about 60-plus years ago. Habitat type is ponderosa pine/snowberry. Approximately 93 percent of the stand is 65-year-old ponderosa pine with a few scattered old growth pine. The remaining 7 percent is young Douglas-fir. Average height of the main canopy is about 60 feet. Average crown width is approximately 12 feet.

i. <u>Plot 9 - West Sweeney Creek</u>. The West Sweeney plot is located in the NE1/4 sec. 20, T. 10 N., R. 20 W., at an elevation of 3,900 feet with a southeast aspect. Average slope is 20 to 30 percent. Most of the trees are ponderosa pine with about 5 percent Douglas-fir. Two age classes of pine are present. One is 50 years with crown heights of 50 to 70 feet and average crown diameters of 15 feet. There are approximately 20 trees per age in this age class. A younger age class of about 20 years has 50 to 60 trees per acre with an average height of 20 to 30 feet and crown diameters of 10 to 15 feet.

j. <u>Plot 10 - Sawdust Gulch</u>. The Sawdust plot is located in the NE1/4 sec. 36, T. 5 N., R. 20 W. at an elevation of 5,600 feet. The plot is located on top of a ridge (southeast aspect) with an average slope of 15 percent. The area was logged 60-plus years ago and had been moderately grazed by cattle. Very little bare soil is exposed. Habitat type is Douglas-fir/snowberry. The stand is composed of about 60 percent ponderosa pine with the remainder being Douglas-fir. An old-growth ponderosa pine stand of approximately 40 to 50 trees per acre overtops a 60-year-old stand of ponderosa pine and Douglas-fir. Trees are more or less in clumps with openings between clumps. There are approximately 250 trees per acre. The old-growth canopy is about 90 to 100 feet. The canopy of the younger stand is about 50 to 60 feet. Average crown width is approximately 25 feet for the older-growth trees and 15 feet for the younger trees.

k. <u>Plot 11 - Upper Blodgett Creek</u>. The Upper Blodgett plot is located in the NE1/4 sec. 16, T. 6 N., R. 21 W. at an elevation of

4,400 feet. This unit is very similar to the Lower Blodgett unit except it is located about 300 feet higher. The average slope is about 20 percent with places up to 50 percent.

1. Plot 12 - South Bear Creek. The South Bear Plot is located in the NW1/4 sec. 16, T. 7 N., R. 21 W. at an elevation of 4,250 feet. The area is relatively flat with slopes up to 10 percent. Average slope is about 5 percent. Soils are granitic. The area was logged 60-plus years ago. A light cut was made about 15 years ago. Habitat type is Douglas-fir/snowberry. The stand consists of approximately 67 percent ponderosa pine and 33 percent Douglas-fir. There are approximately 400 trees per acre. The main canopy is composed of 60 to 65-year-old ponderosa pine and Douglas-fir. In addition 25 to 30-year-old reproduction is present. Average height is 65 feet, and average crown width is 16 feet for ponderosa pine and 18 feet for Douglas-fir.

1.6 SPRAY FORMULATION

Spray formulation data are provided in Tables 3 and 4.

1.7 AIRCRAFT AND DISSEMINATION

Bell G-3-B-1 helicopters were used to spray each of the 12 plots. A single helicopter was employed on the six Zectran trials and two helicopters on the six *Bt*. trials. Two helicopters were required on the *Bt*. plots because of the limited load capacity of the helicopter and the requirement to apply 2 gallons per acre on the *Bt*. plots. The helicopters were equipped with a conventional spray system consisting of 59 each Number 80015 T-jet nozzles (Figures 2 and 3).

Table 3. Spray Mixture per Gallon - Zectran Trials

Trial	[a]FS-15 Zectran (gal)	Fuel Oil (gal)	DuPont Oil Red Dye (lb)
Z-1-1	0.1	0.9	0.03214
Z-1-2	0.1	0.9	0.03214
Z-1-3	0.1	0.9	0.03214
Z-2-4	0.2	0.8	0.06643
Z-2-5	0.2	0.8	0.06643
Z-2-6	0.2	0.8	0.06643

[a] FS-15 contains 0.15 pounds of Zectran per gallon.

Table 4. Spray Mixture per Gallon - Bacillus thuringiensis Trials

Trial	Bt. (lb)	Water (gal)	Rhodamine B Extra S (lb)	Yellow Zinc Cadmium Sulfide (lb)	Bio Film (lb)
B-1-1	0.25	1.0	0.008346	0.05842	0.009375
B-1-2	0.25	1.0	0.008346	0.05842	0.009375
B-1-3	0.25	1.0	0.008346	0.05842	0.009375
B-2-4	0.50	1.0	0.008436	--	0.009375
B-2-5	0.50	1.0	0.008436	--	0.009375
B-2-6	0.50	1.0	0.008436	--	0.009375

Figure 2. Bell G-3 Spray Helicopter Showing Insecticide Hopper and Spray Boom

Figure 3. Spray Boom on Bell G-3 Helicopter

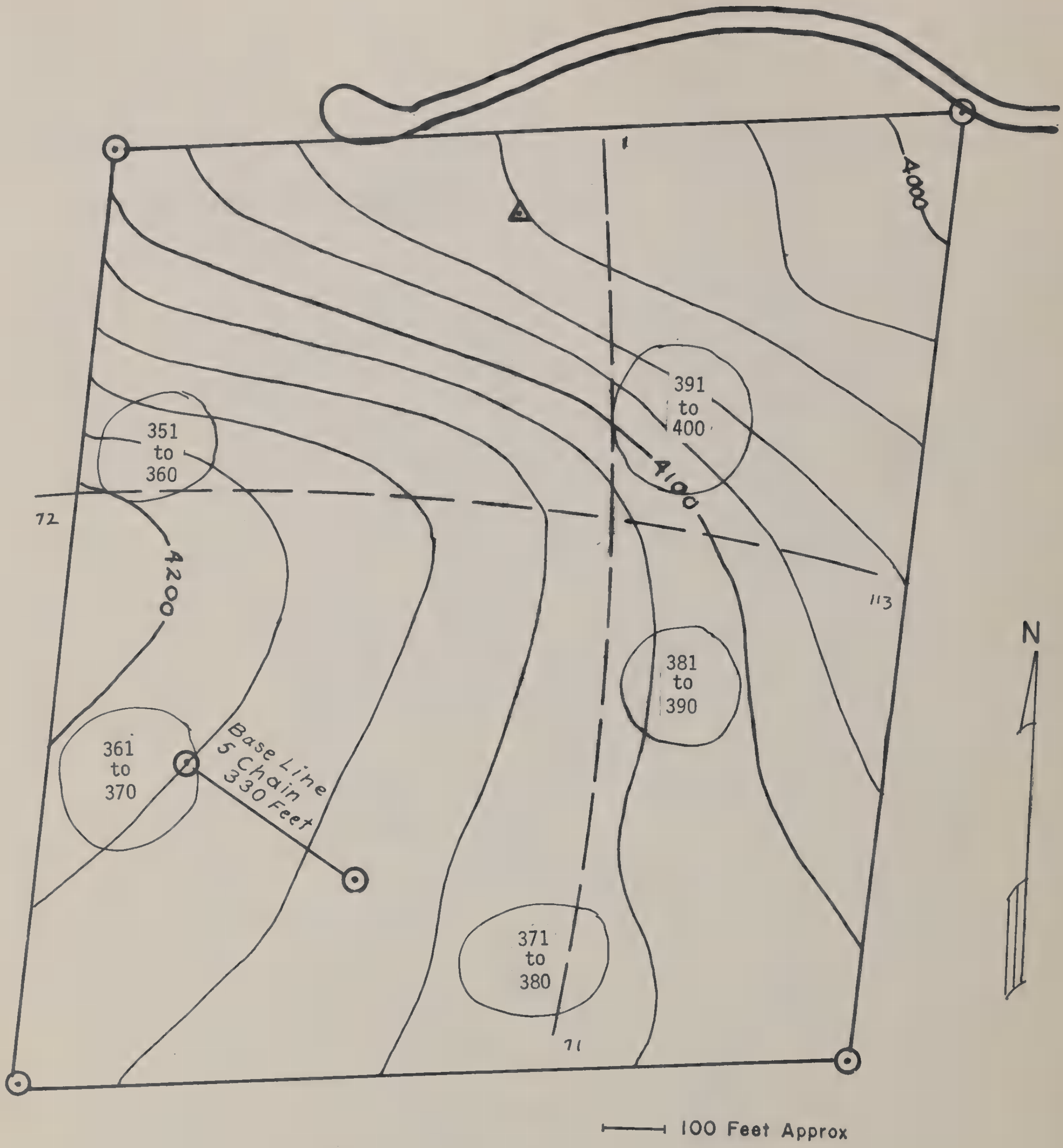
Each plot was sprayed by the swath method with the swaths programed to be 63 feet apart, resulting in 20 to 22 swaths per 40-acre plot. The helicopter speed was 45 miles per hour; the release altitude was 50 feet above tree-top level.

Considerable detail was given to meteorology and aircraft operations in order to maximize the deposition of the spray material within the spray plot boundaries. To minimize drift, the helicopter flew at a relatively low altitude and the initial swath was offset upwind of the plot to allow for the increase in fall angle of the spray caused by the wind and slope of the terrain. Trials were conducted in the early morning hours when the winds were minimal, and before development of strong convective activity and lapse conditions which cause turbulent mixing of the spray cloud and dilution in concentration of the spray.

The methods applied for disseminating the spray to the plots was considered critical for satisfying test objectives. Thus, close coordination was maintained between helicopter pilots and ground crews. Aerial and ground reconnaissance missions were conducted by the pilots prior to spraying each plot. The center and each corner of the plots were marked with flags and panels. Smoke grenades were employed in the vicinity of plot center during spray operations. Flagmen were also stationed at plot boundaries on selected plots.

Figures 4 through 32 illustrate each of the spray plots. There are two sets of figures for each of the 12 plots. One figure is a diagram illustrating contour lines, trails, cross-sampling lines, sample tree groupings, and meteorological stations, where applicable. The

second figure is an aerial photograph, or photographs, showing the sample trees or sample-tree groupings by number.



MILL CREEK

LEGEND

Contour (ft)
Sample Line - Cross Configuration
Meteorological Station
Cluster Sampling
Plot Corner

Figure 4. Plot Diagram Mill Creek - Trial Z-1-1

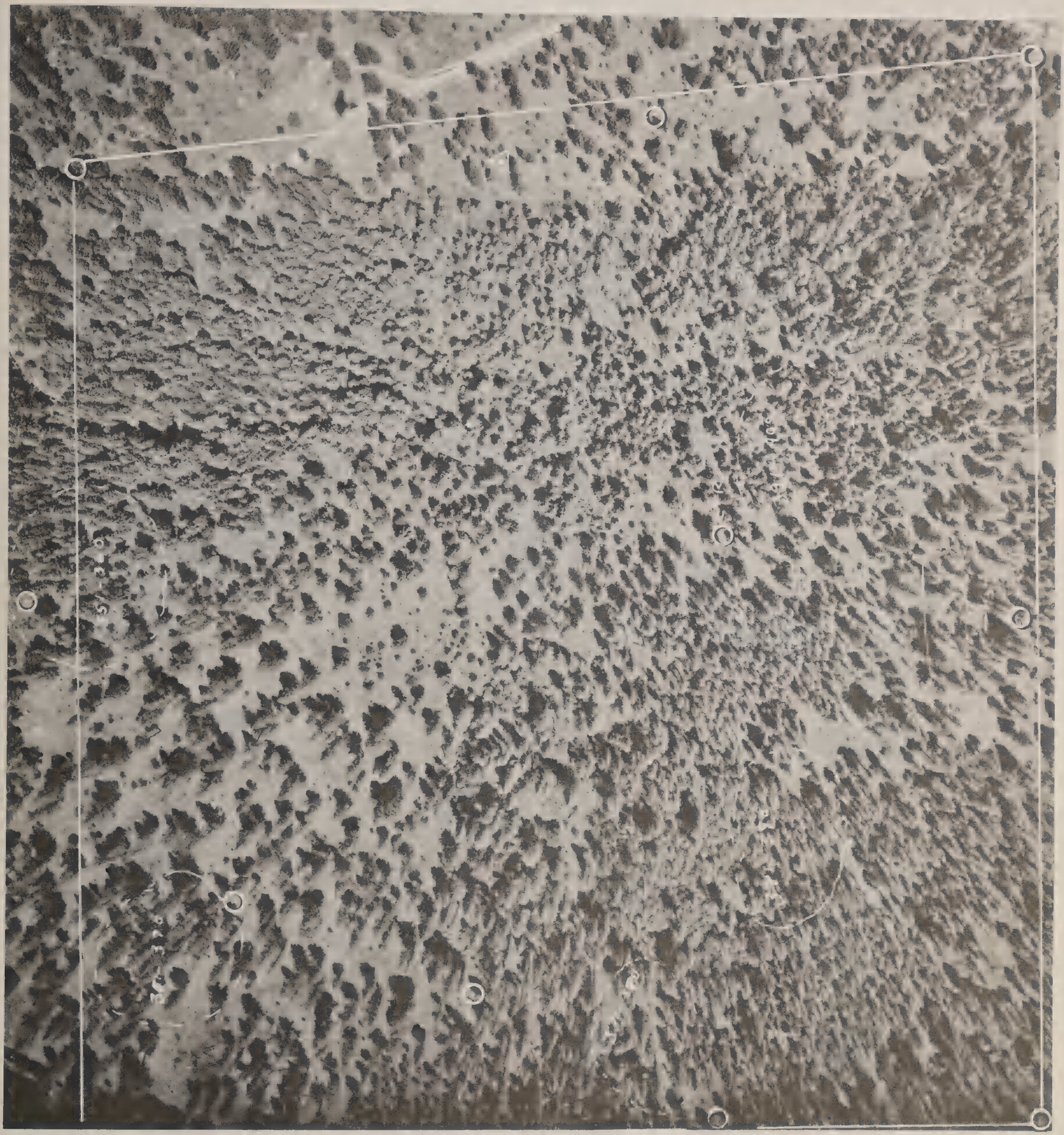
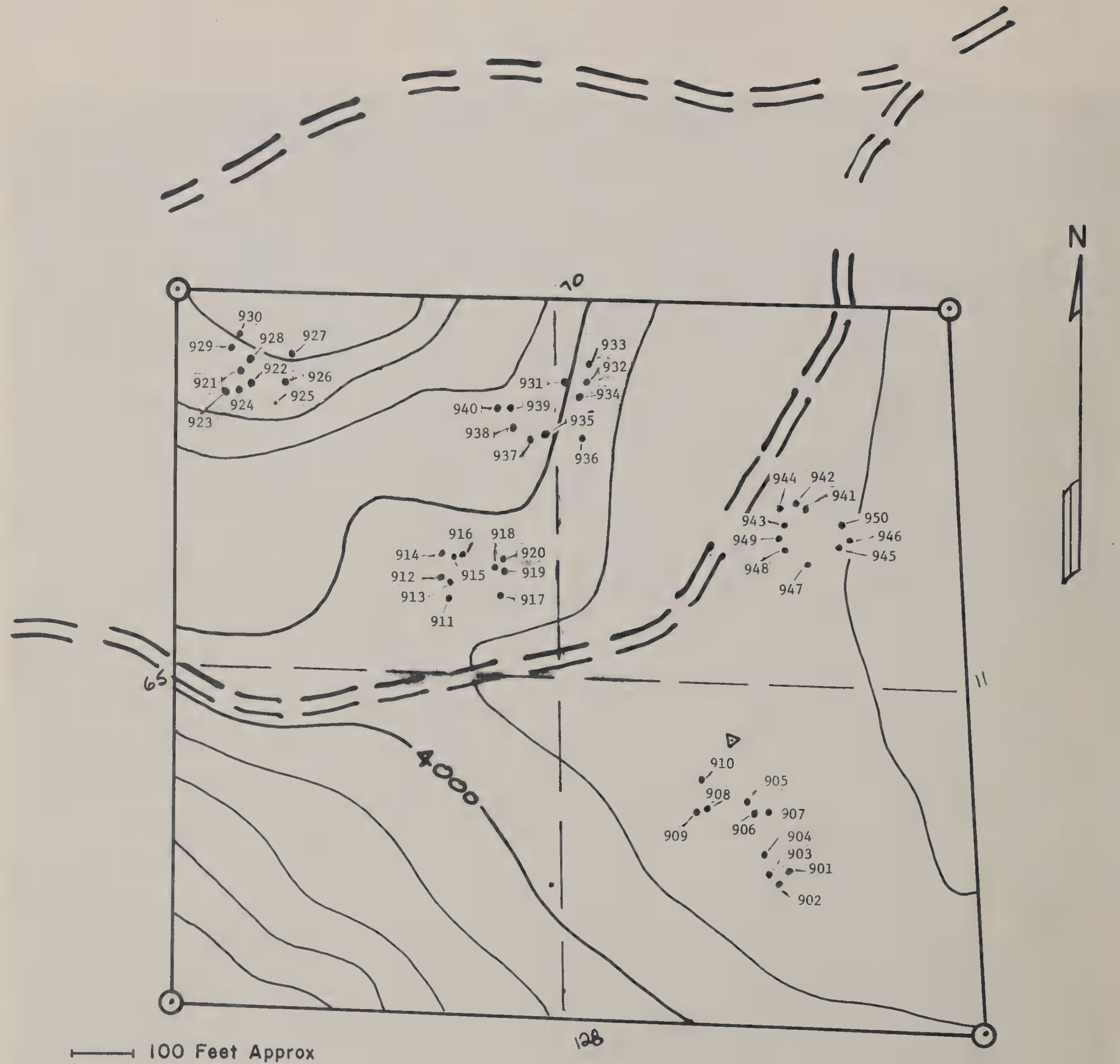


Figure 5. Aerial Photo Mill Creek - Trial Z-1-1



NORTH BEAR

LEGEND

- Contour (ft)
- Sample Line - Cross Configuration
- Meteorological Station
- Sample Tree - Number
- Plot Corner

Figure 6. Plot Diagram North Bear Creek - Trial Z-1-2

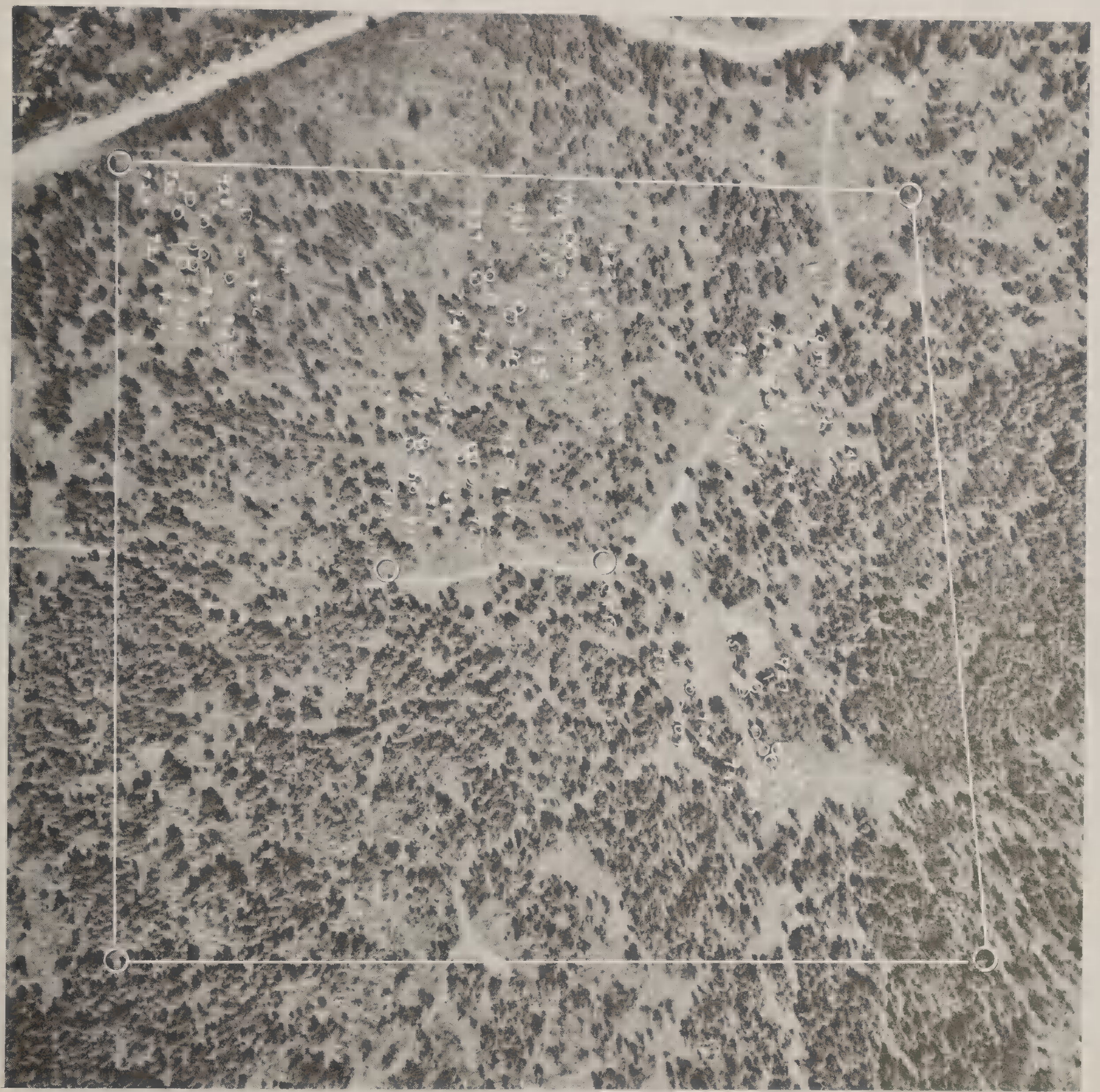
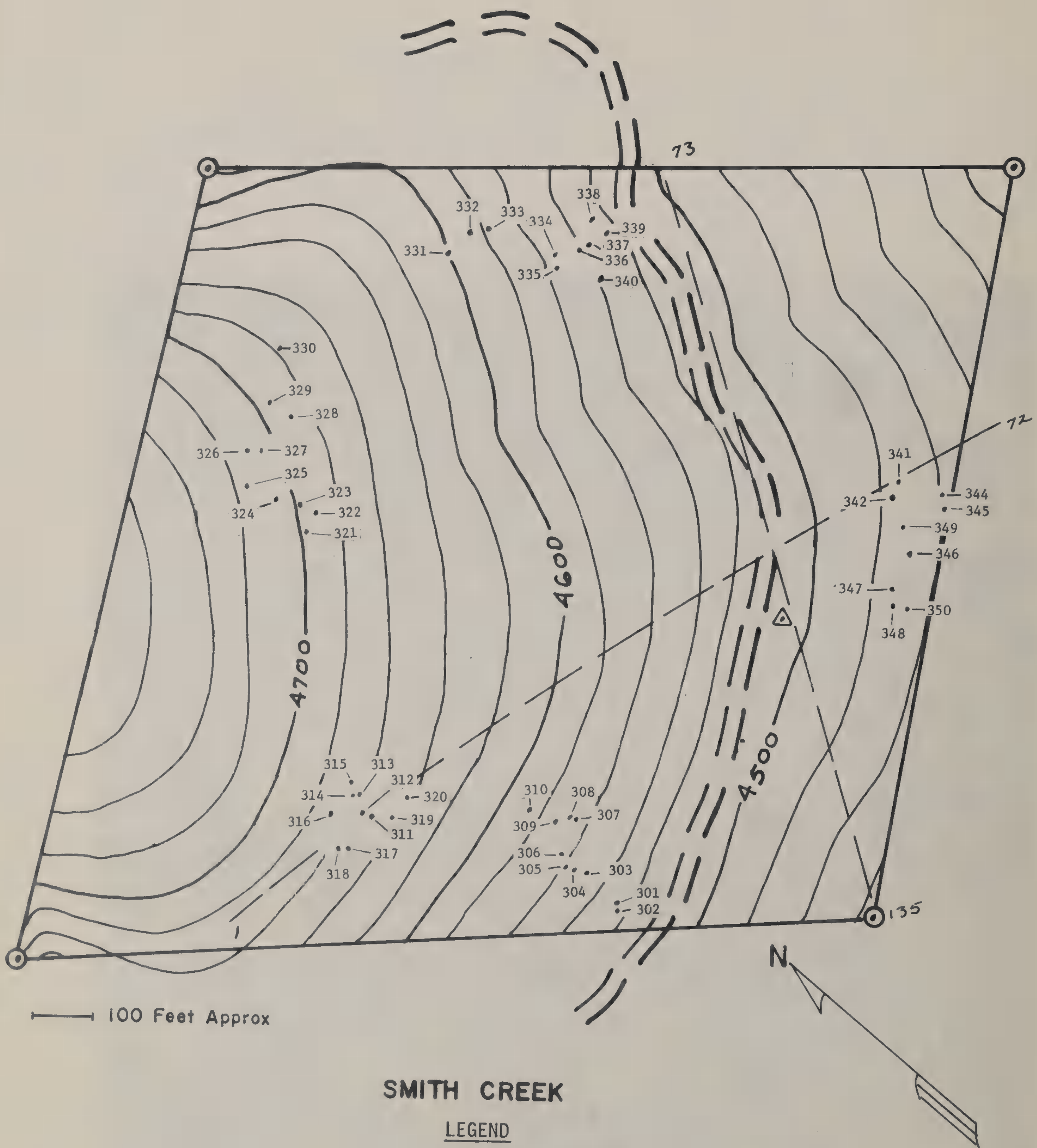


Figure 7. Aerial Photo North Bear Creek - Trial Z-1-2



SMITH CREEK

LEGEND

- Contour (ft)
- Sample Line - Cross Configuration
- Meteorological Station
- Sample Tree - Number
- Plot Corner

Figure 8. Plot Diagram Smith Creek - Trial Z-1-3

Figure 9. Aerial Photo Smith Creek - Trial Z-1-3

Figure 10. Aerial Photo Smith Creek - Trial Z-1-3

Figure 11. Aerial Photo Smith Creek - Trial Z-1-3

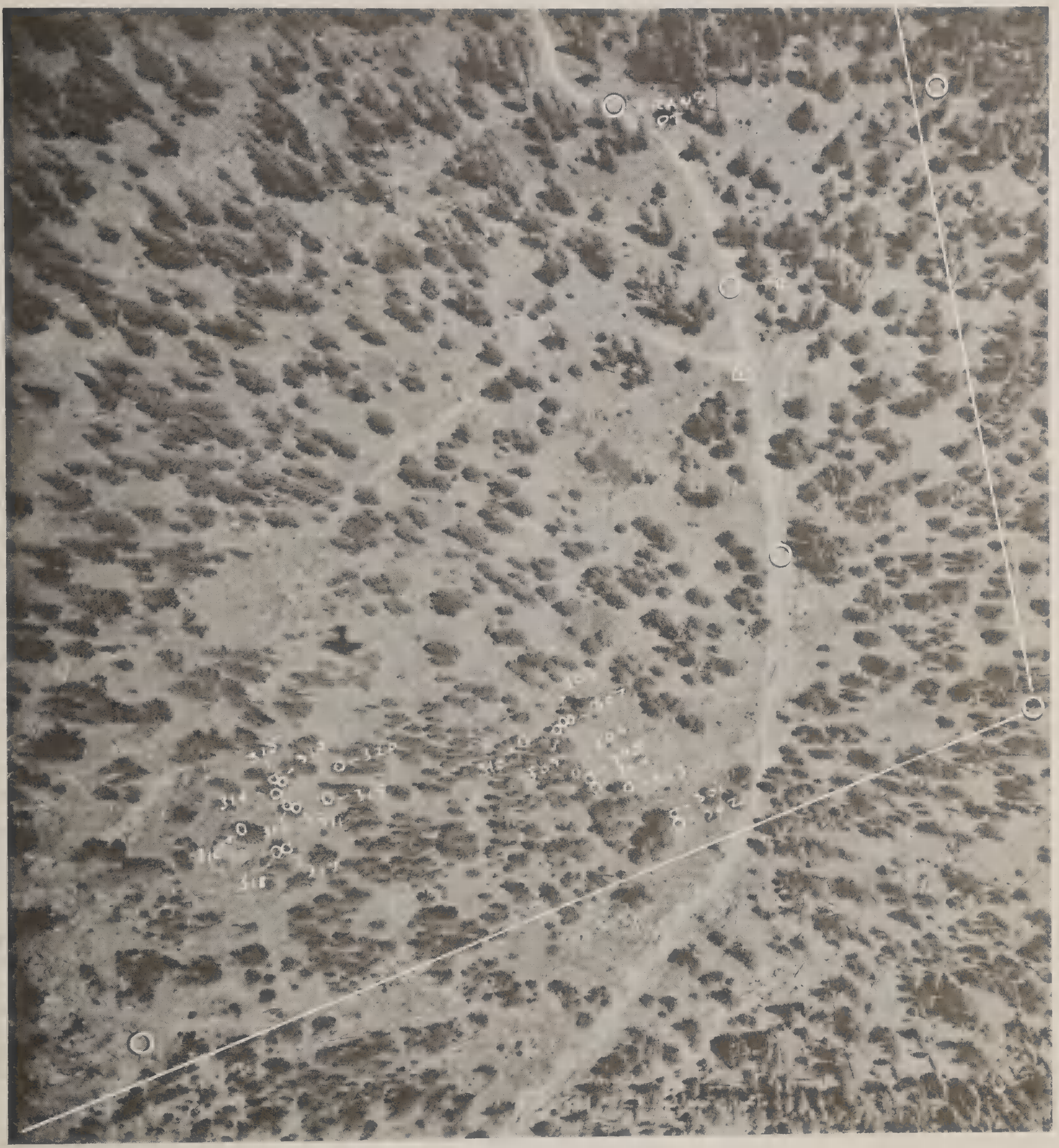
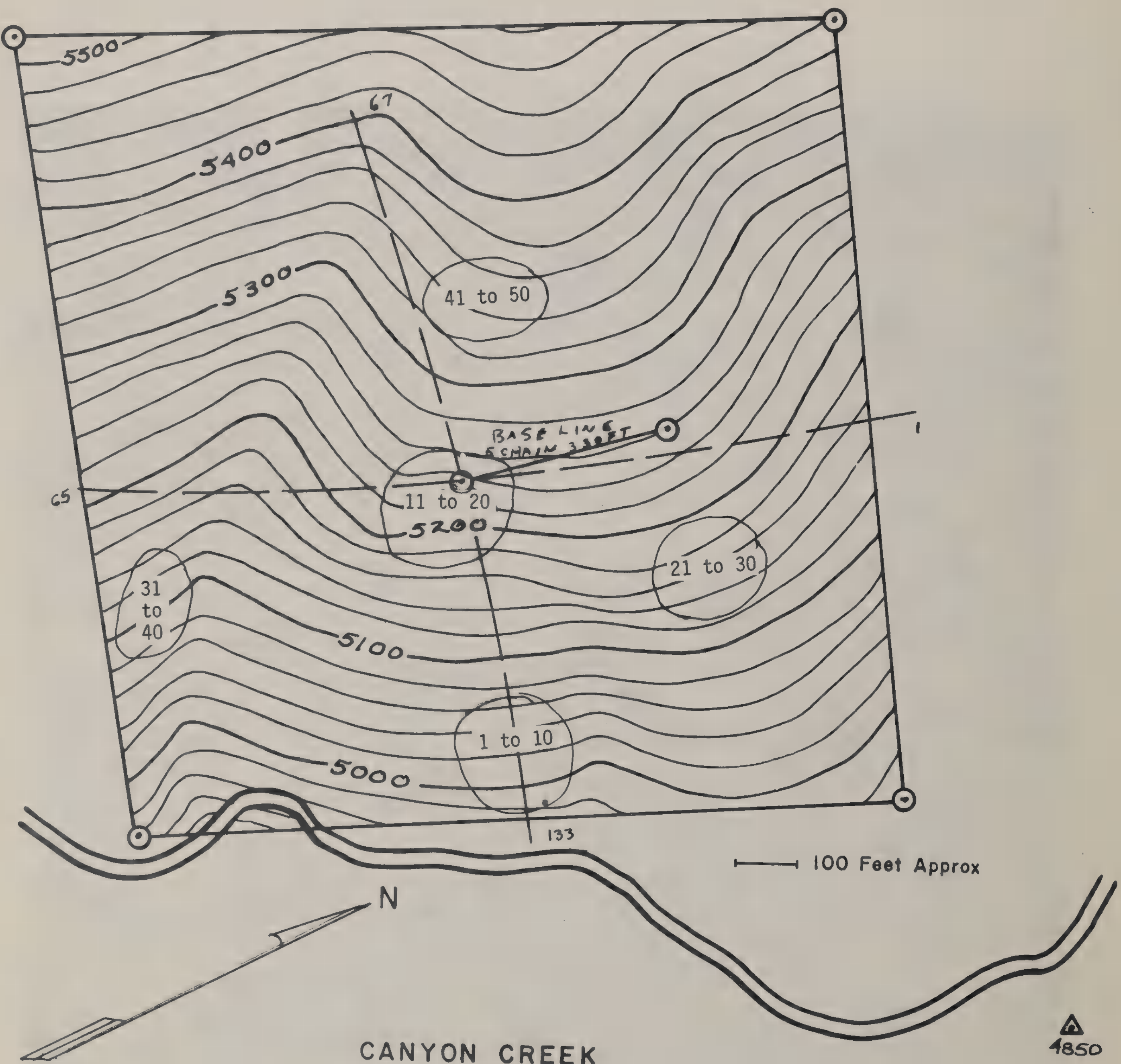


Figure 12. Aerial Photo Smith Creek - Trial Z-1-3



CANYON CREEK

LEGEND

Contour (ft)

Sample Line - Cross Configuration

Meteorological Station

Cluster Sampling

Plot Corner

Figure 13. Plot Diagram Canyon Creek - Trial Z-2-4

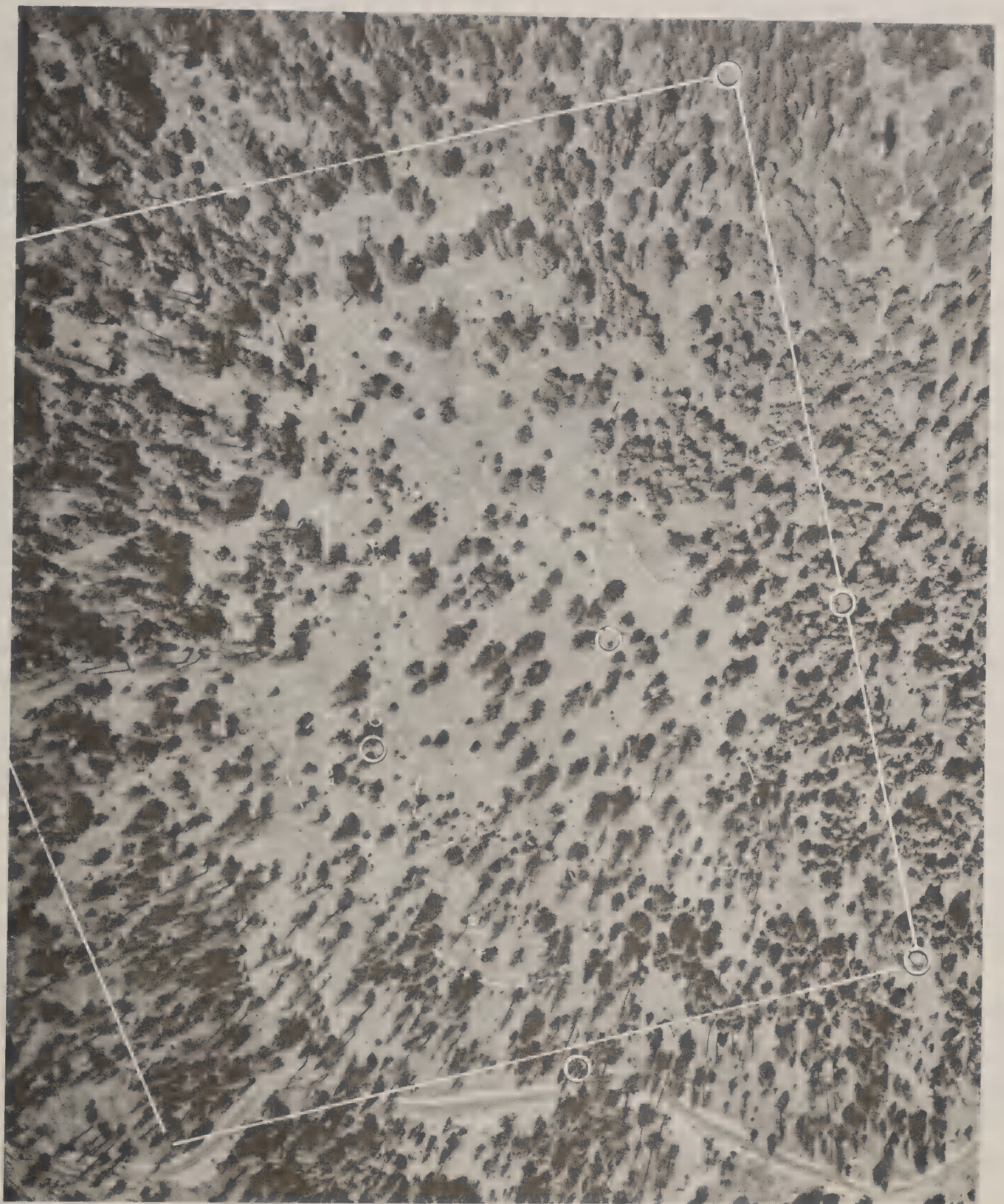


Figure 14. Aerial Photo Canyon Creek - Trial Z-2-4

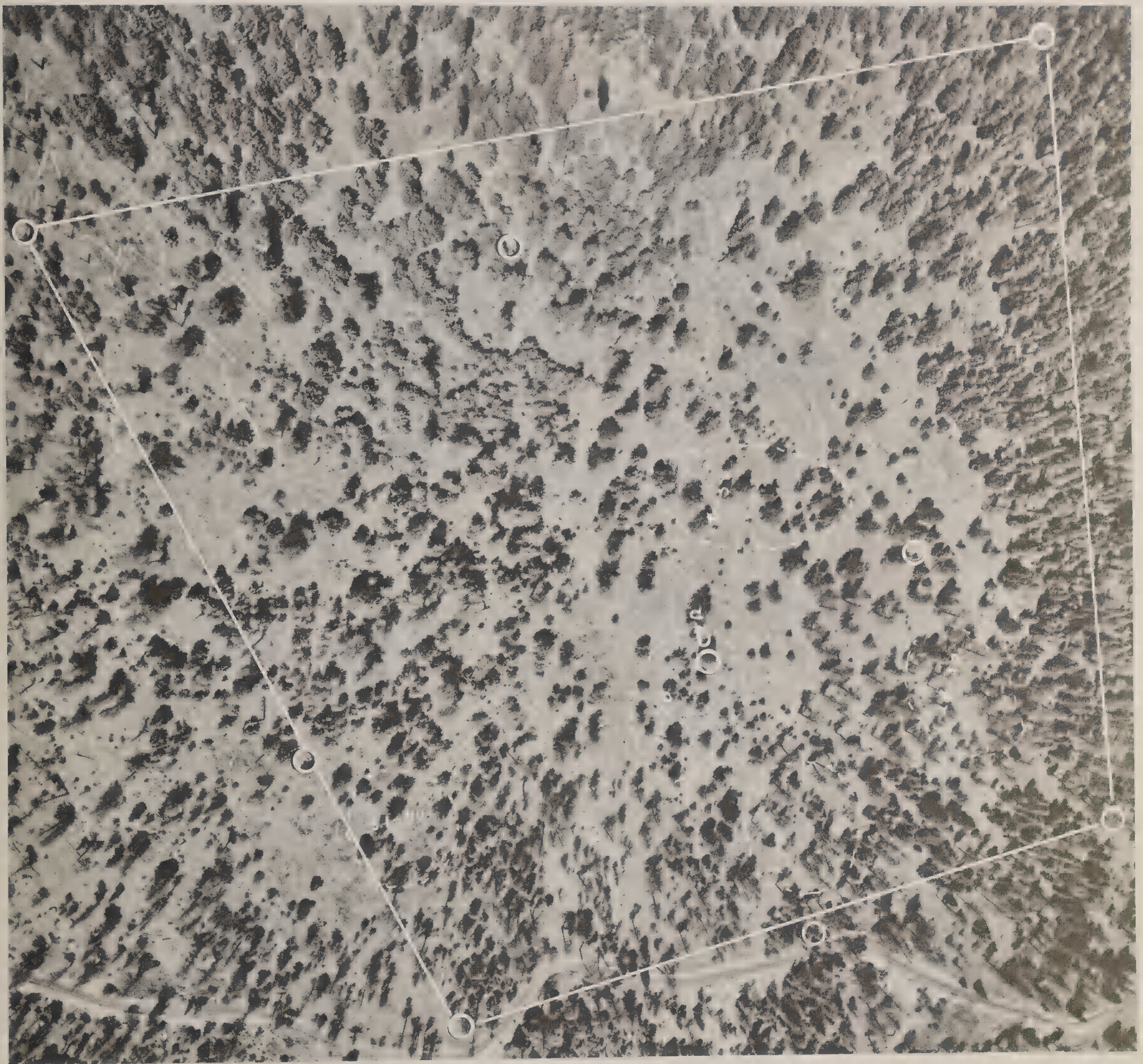
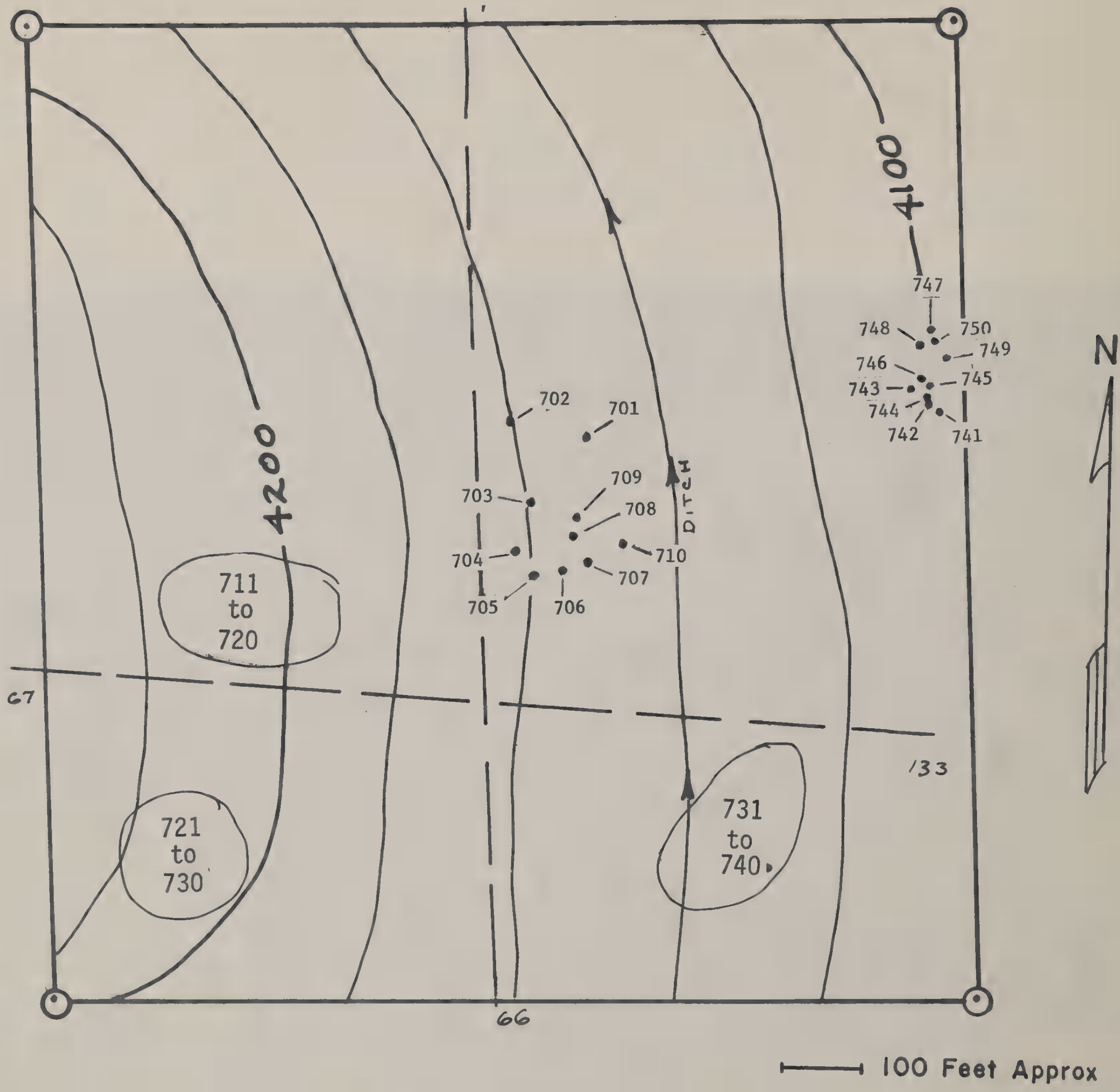


Figure 15. Aerial Photo Canyon Creek - Trial Z-2-4



LOWER BLODGETT

LEGEND

~	Contour (ft)
- - -	Sample Line - Cross Configuration
△	Meteorological Station
•	Sample Tree - Number
◯	Cluster Sampling
⊙	Plot Corner

Figure 16. Plot Diagram Lower Blodgett Creek - Trial Z-2-5

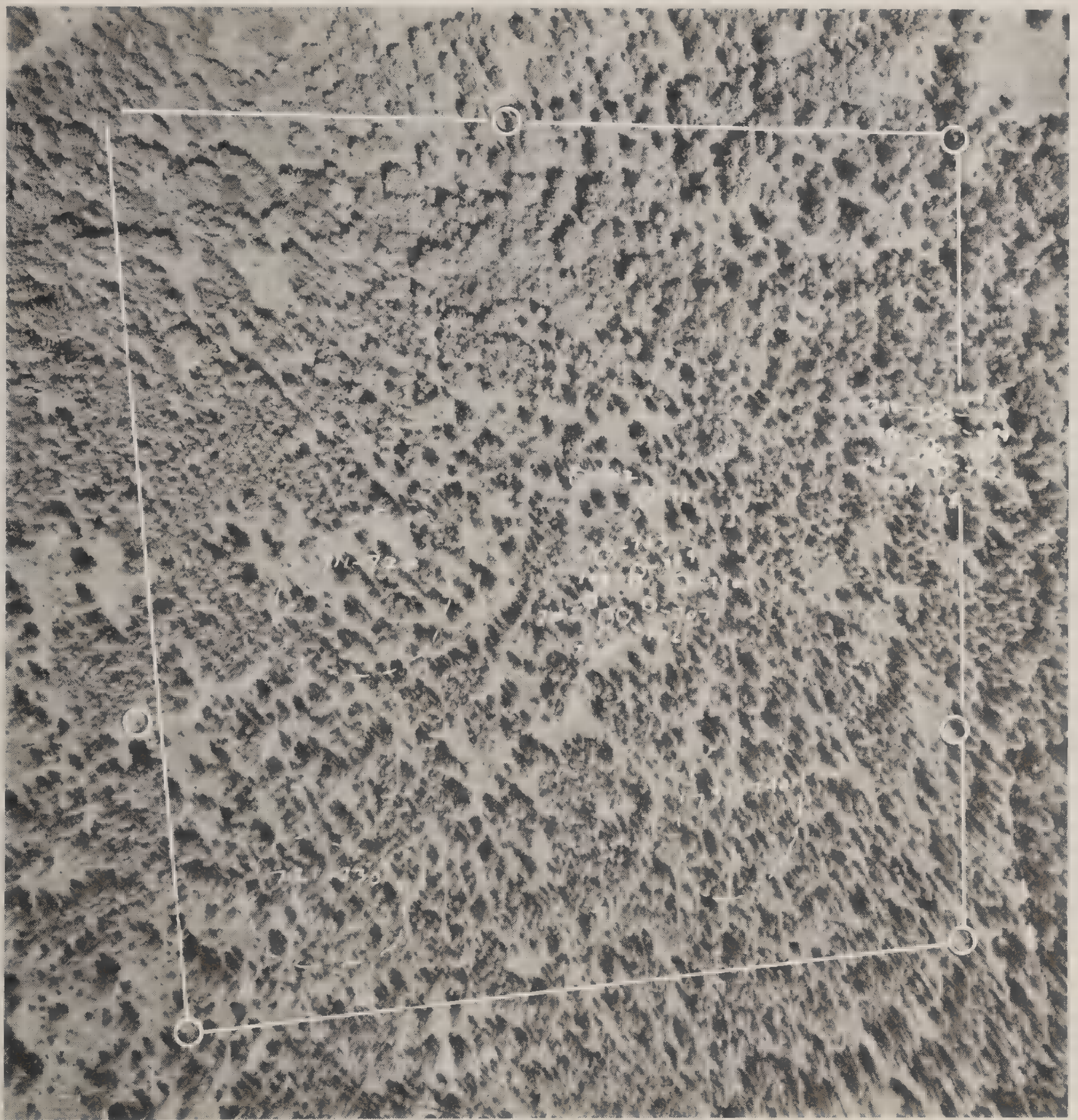


Figure 17. Aerial Photo Lower Blodgett Creek - Trial Z-2-5

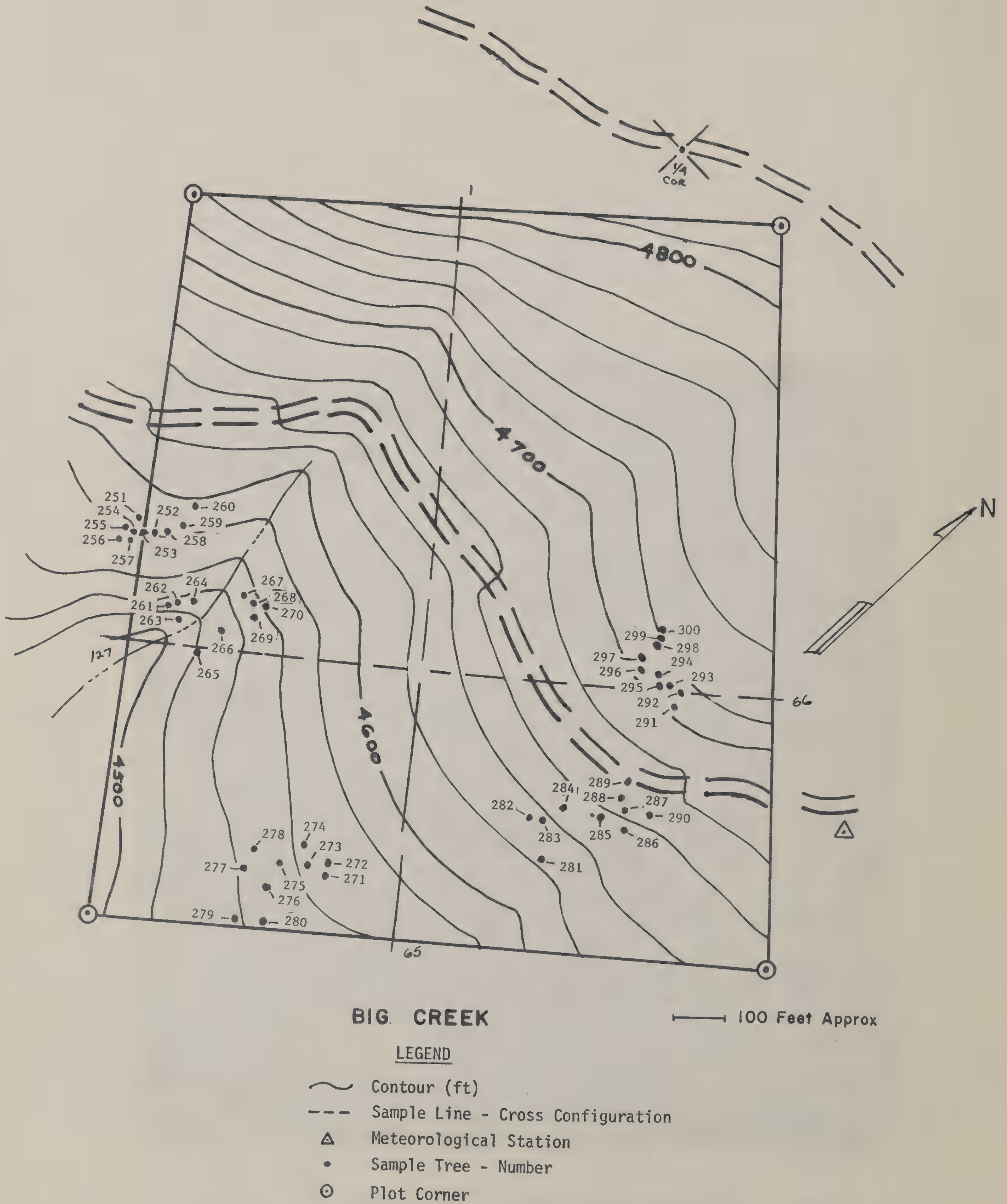


Figure 18. Plot Diagram Big Creek - Trial Z-2-6

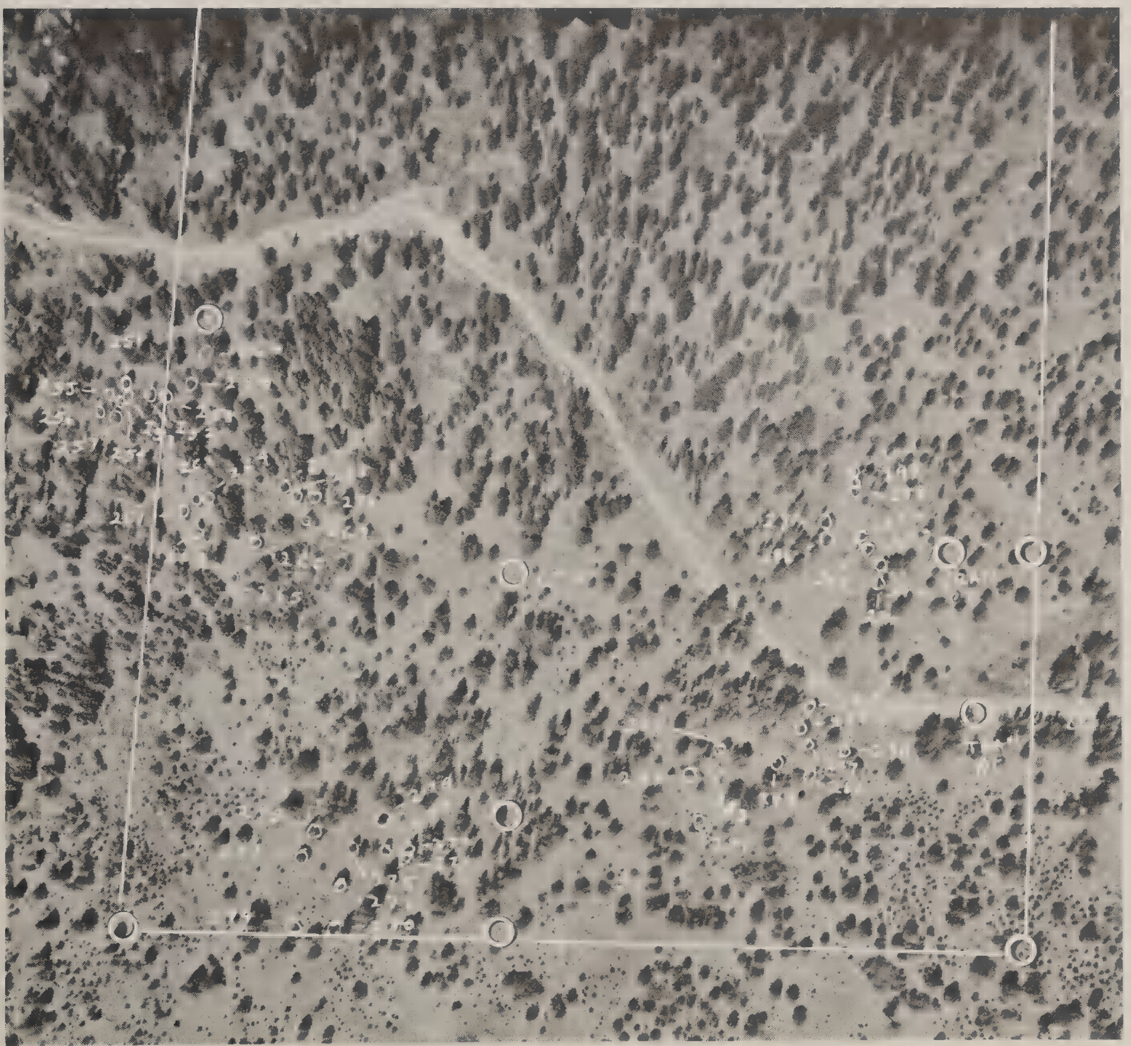
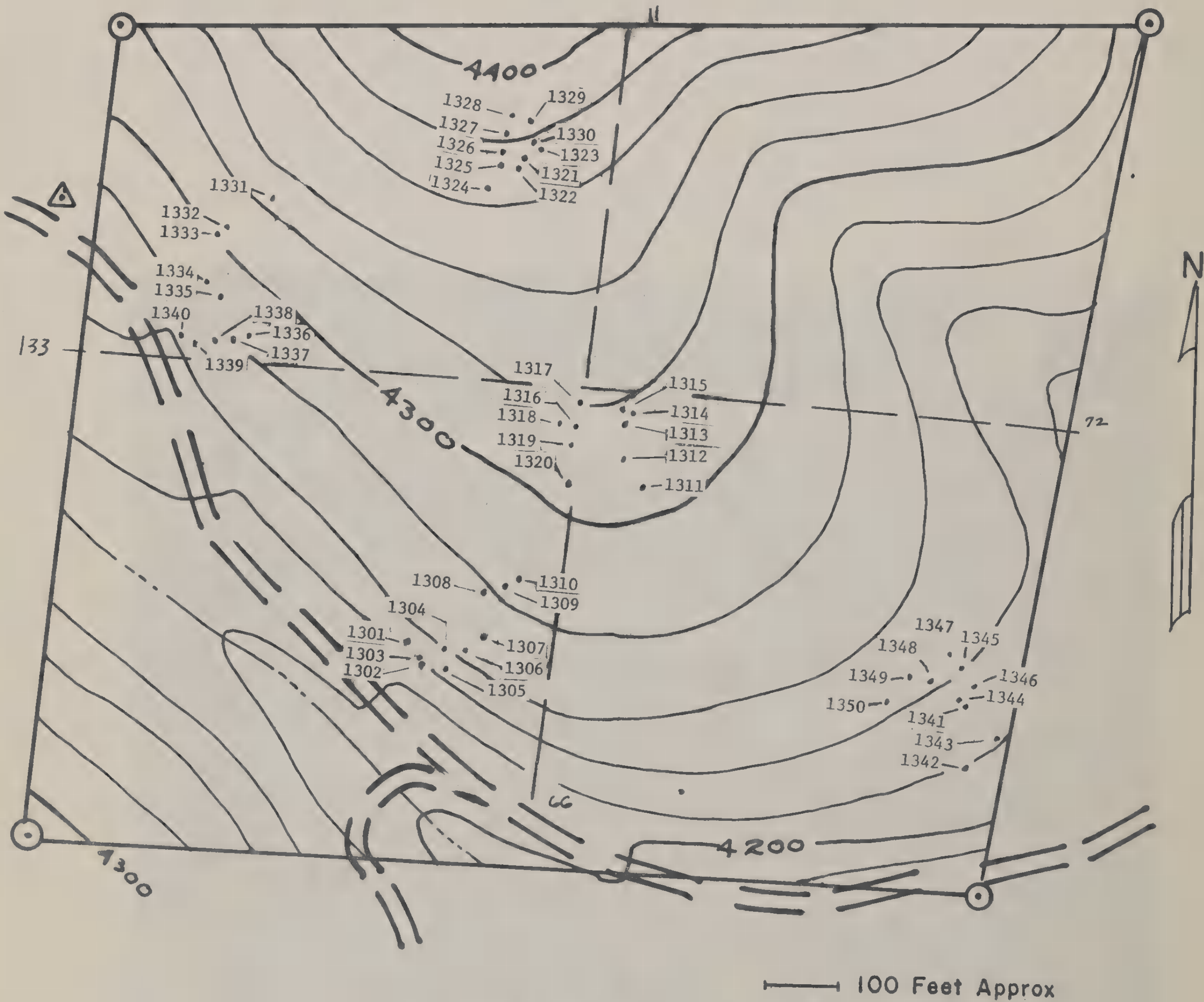


Figure 19. Aerial Photo Big Creek - Trial Z-2-6

Figure 20. Aerial Photo Big Creek - Trial Z-2-6



GASH CREEK

LEGEND

Contour (ft)
Sample Line - Cross Configuration
Meteorological Station
Sample Tree - Number
Plot Corner

Figure 21. Plot Diagram Gash Creek - Trial B-1-1

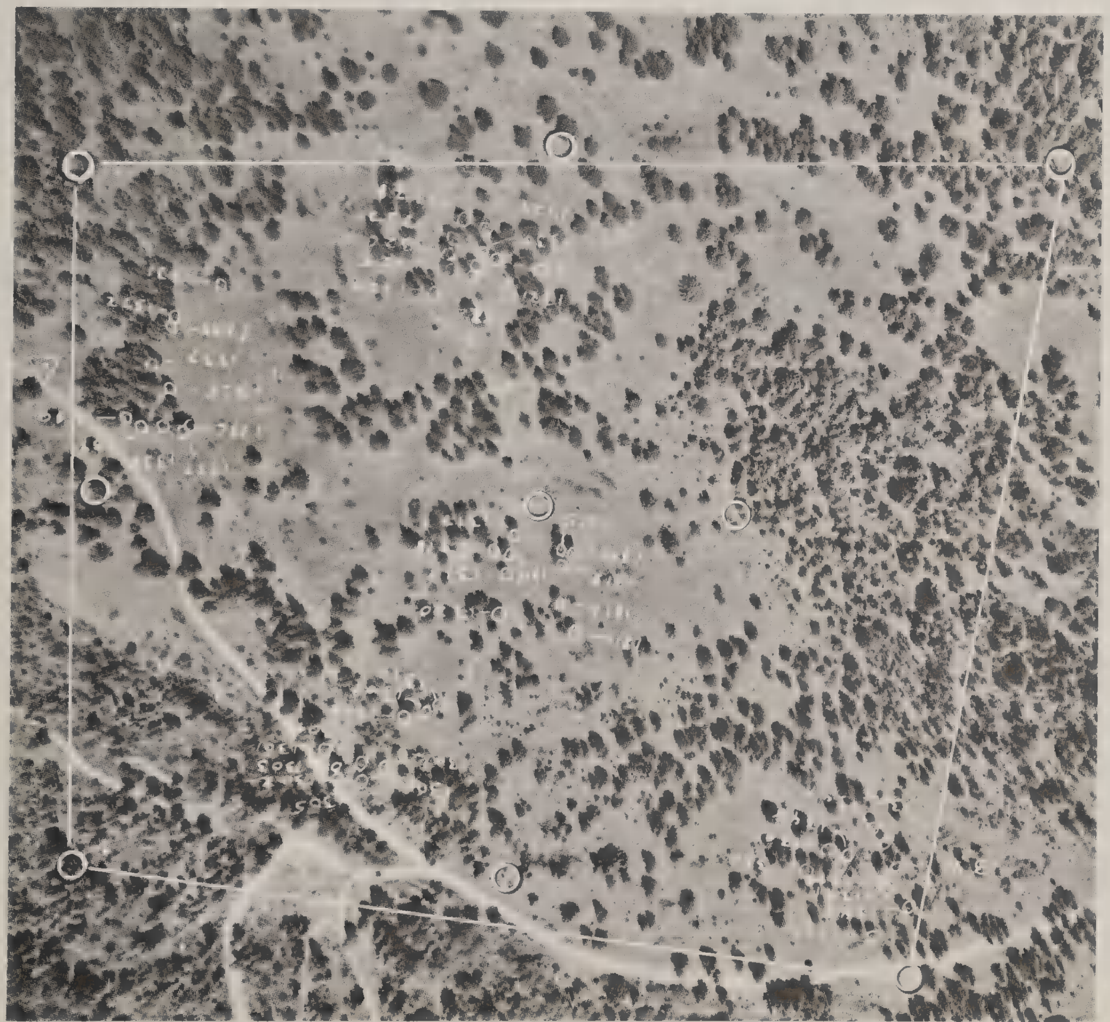
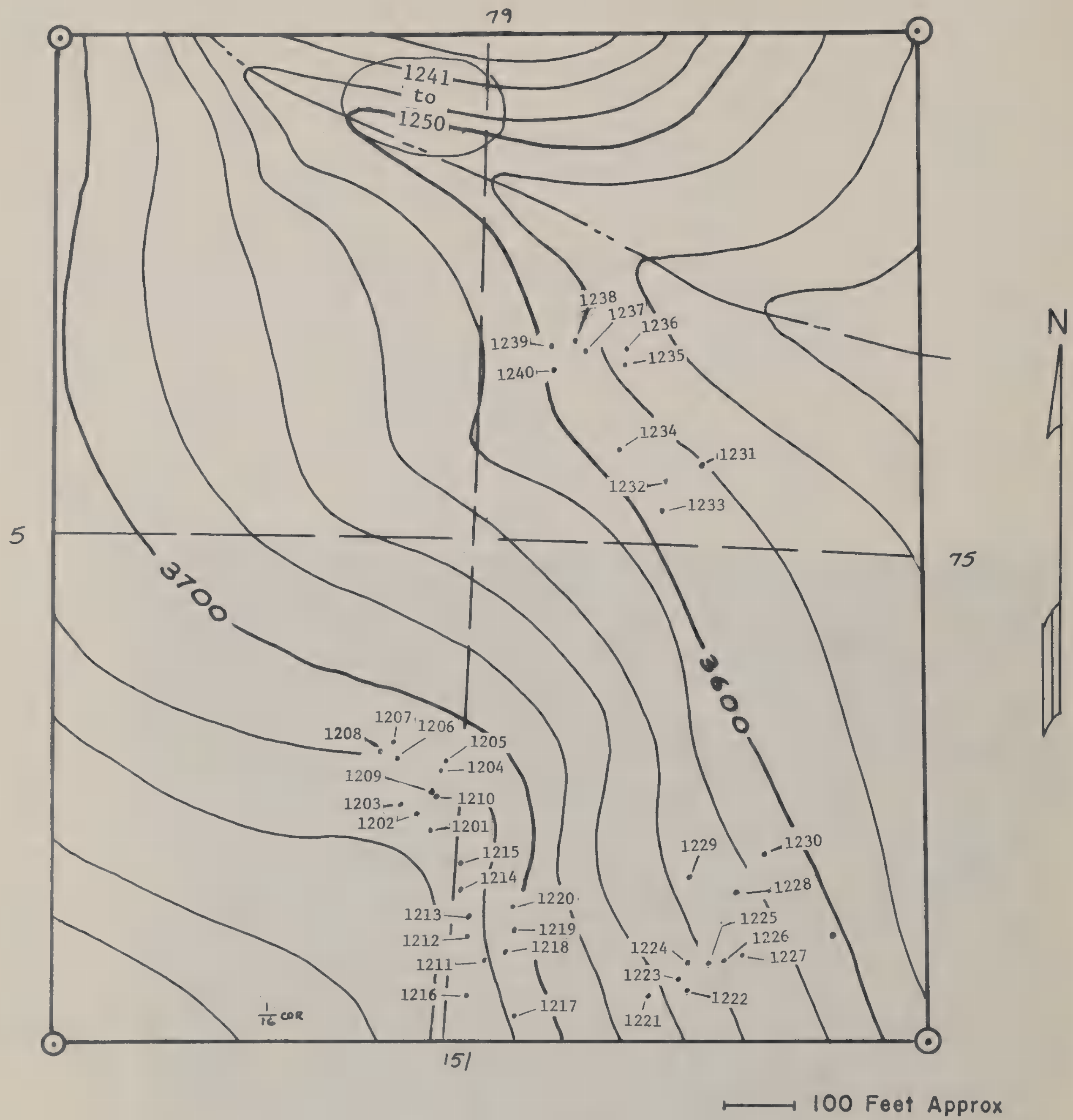


Figure 22. Aerial Photo Gash Creek - Trial B-1-1



EAST SWEENEY

LEGEND

Contour (ft)

Sample Line - Cross Configuration

Meteorological Station

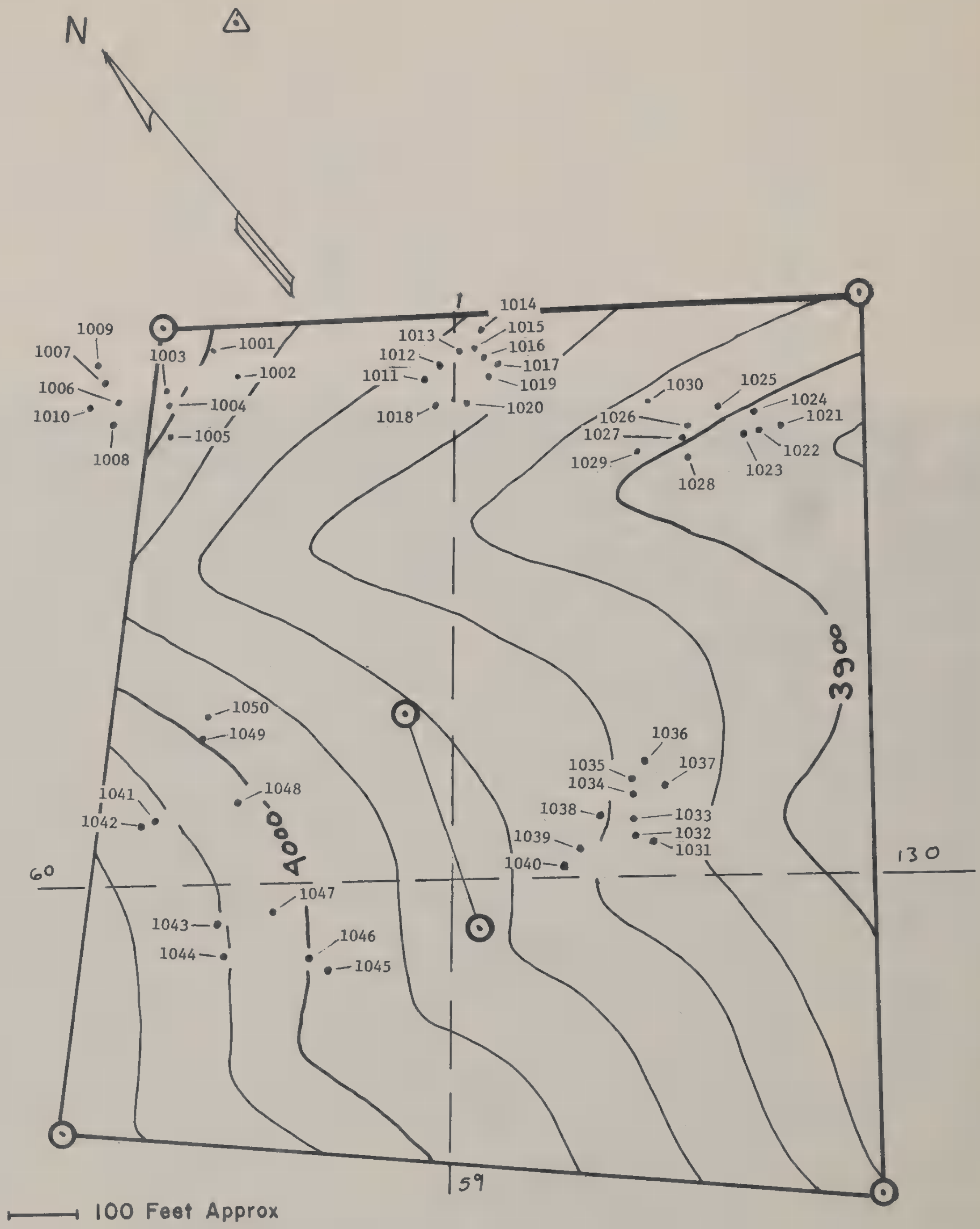
Sample Tree - Number

Cluster Sampling

Plot Corner

Figure 23. Plot Diagram East Sweeney Creek - Trial B-1-2

Figure 24. Aerial Photo East Sweeney Creek - Trial B-1-2



WEST SWEENEY

LEGEND

- Contour (ft)
- Sample Line - Cross Configuration
- Meteorological Station
- Sample Tree - Number
- Plot Corner

Figure 25. Plot Diagram West Sweeney Creek - B-1-3

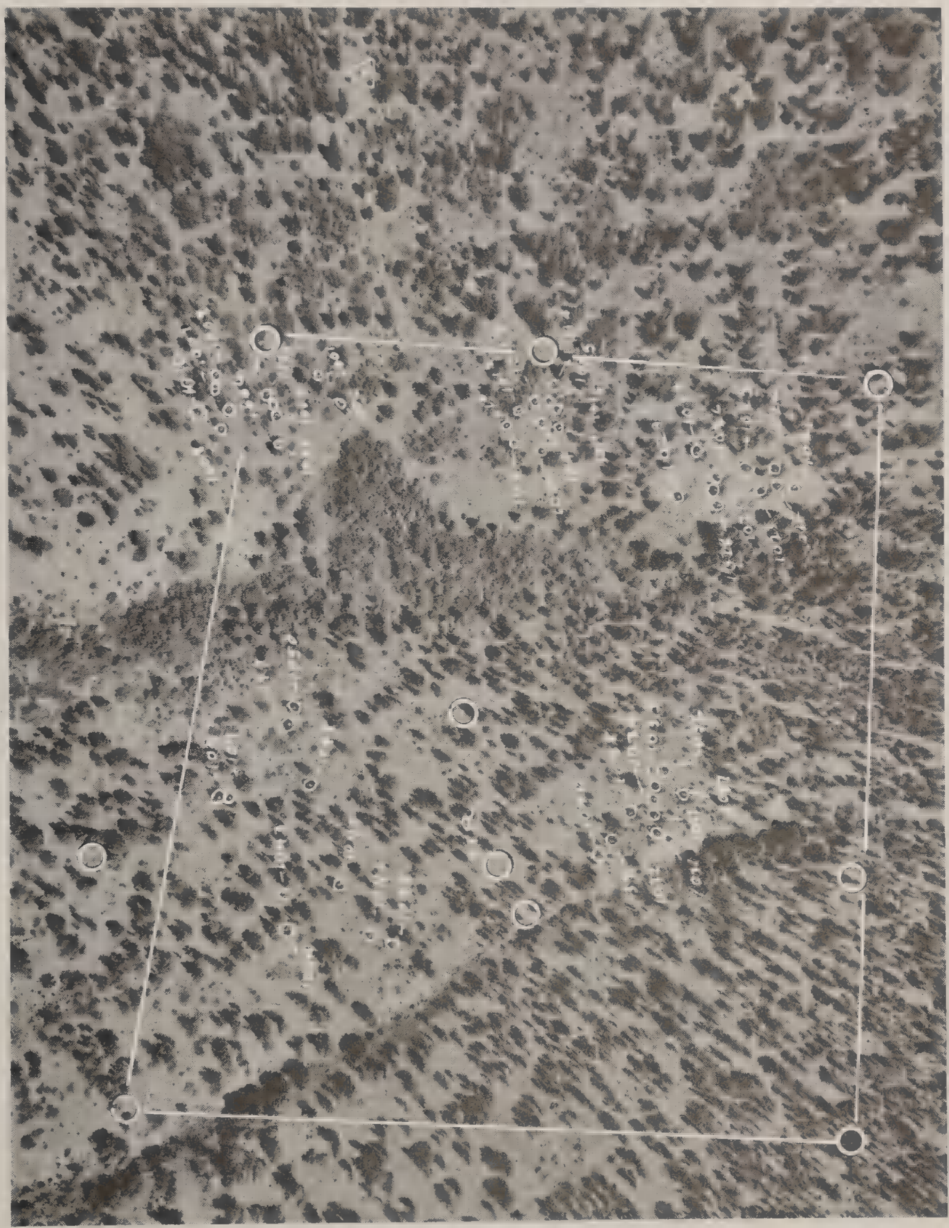


Figure 26. Aerial Photo West Sweeney Creek - Trial B-1-3

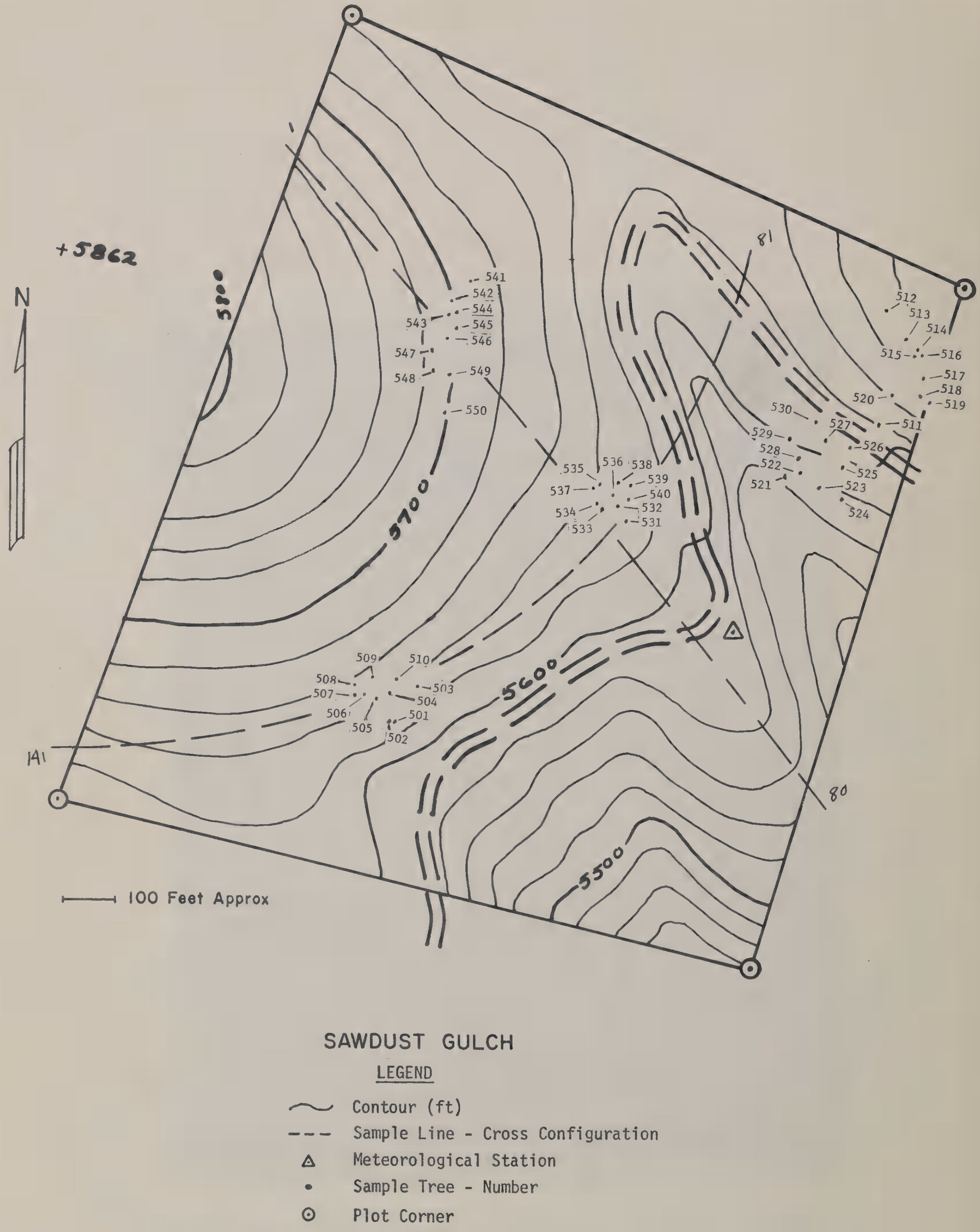


Figure 27. Plot Diagram Sawdust Gulch - Trial B-2-4

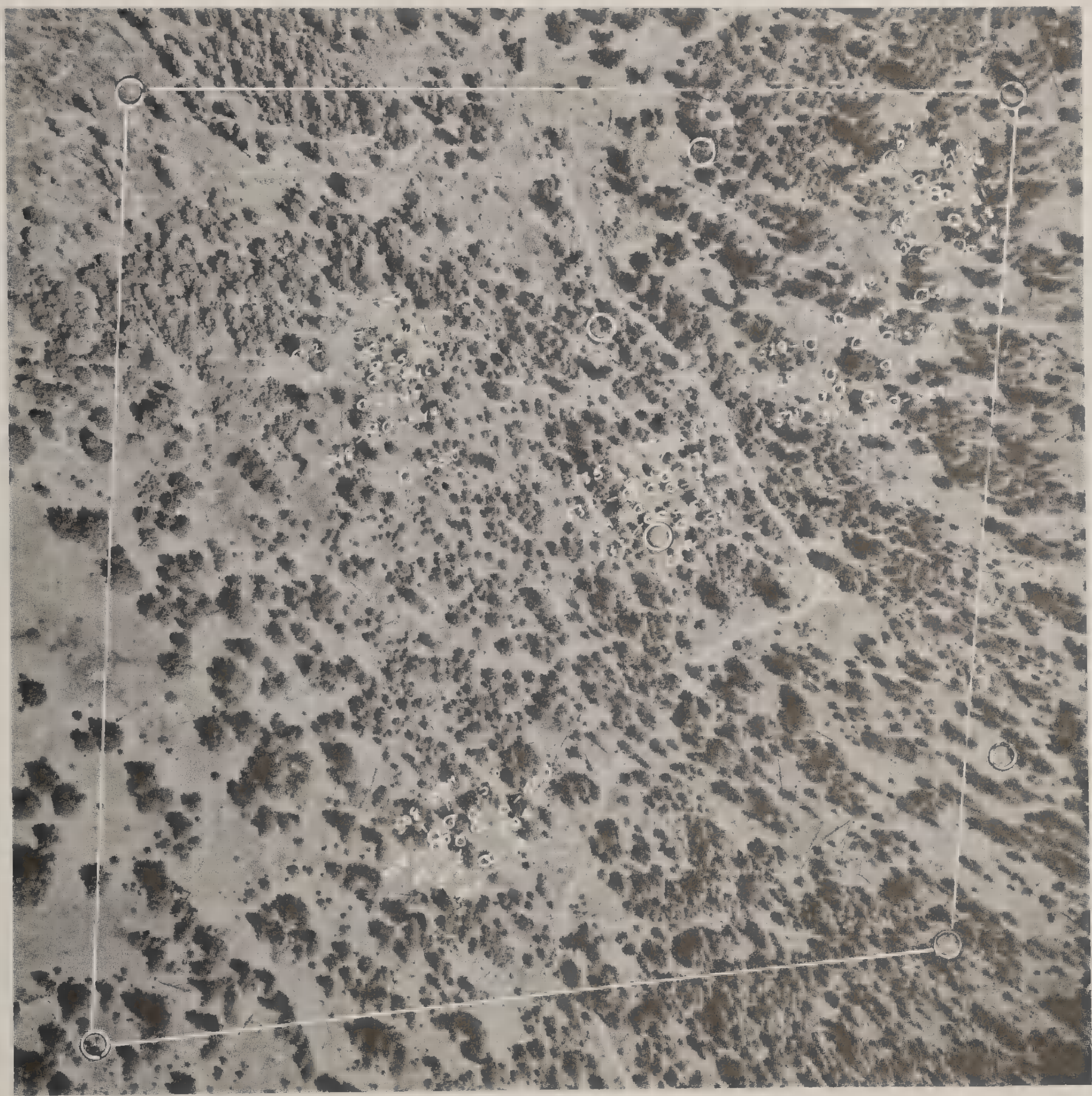
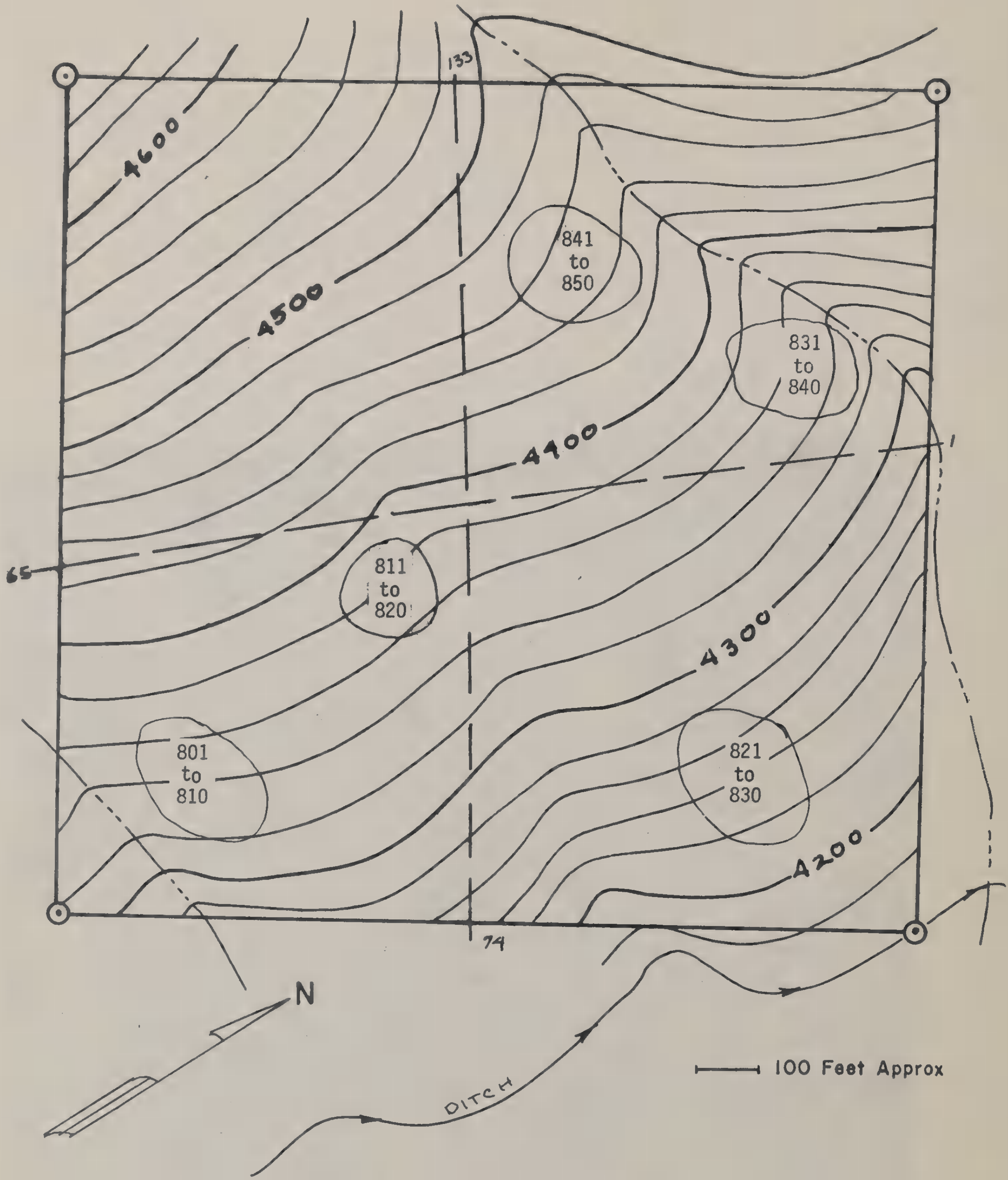


Figure 28. Aerial Photo Sawdust Gulch - Trial B-2-4



UPPER BLODGETT

LEGEND

- Contour (ft)
- Sample Line - Cross Configuration
- Meteorological Station
- Cluster Sampling
- Plot Corner

Figure 29. Plot Diagram Upper Blodgett - Trial B-2-5

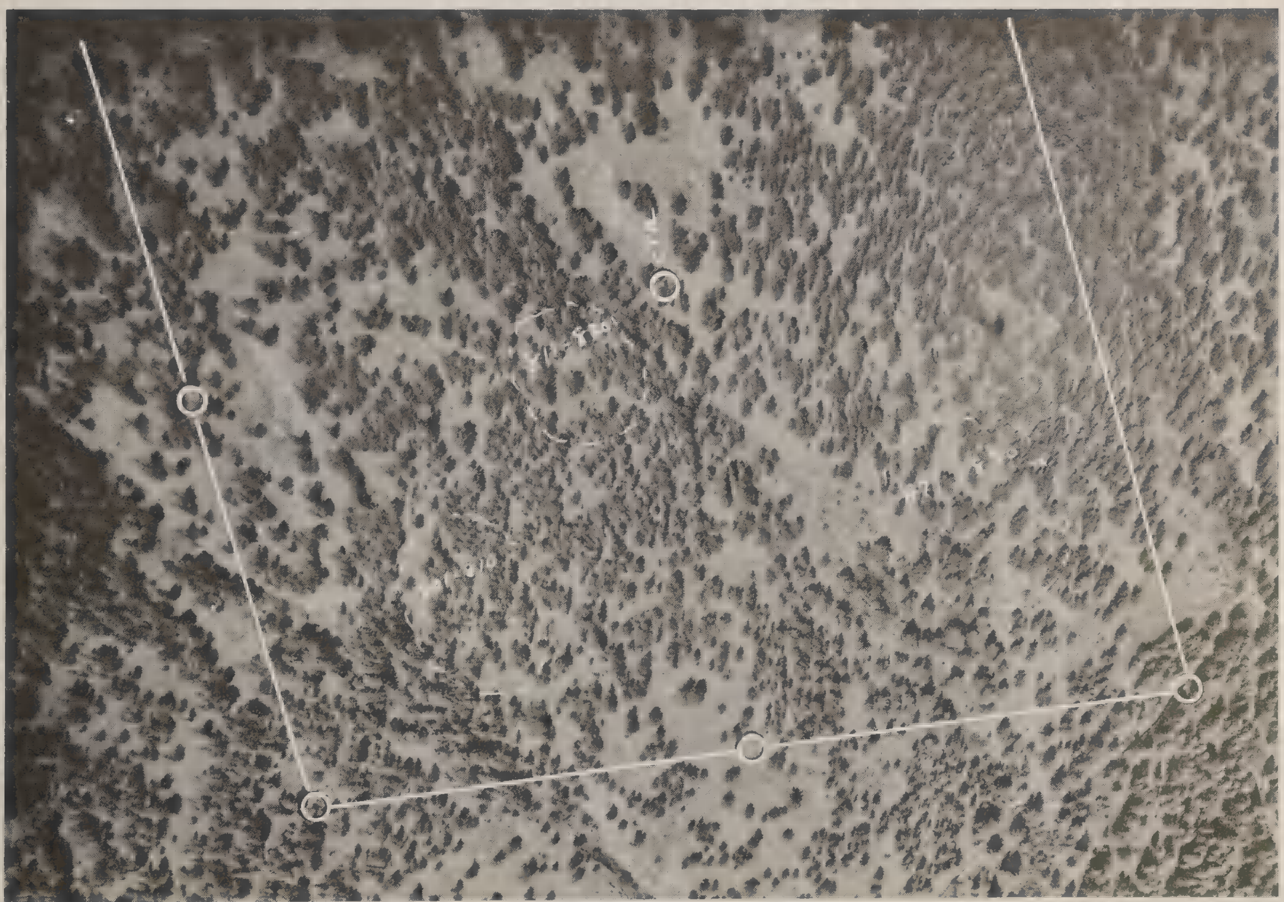
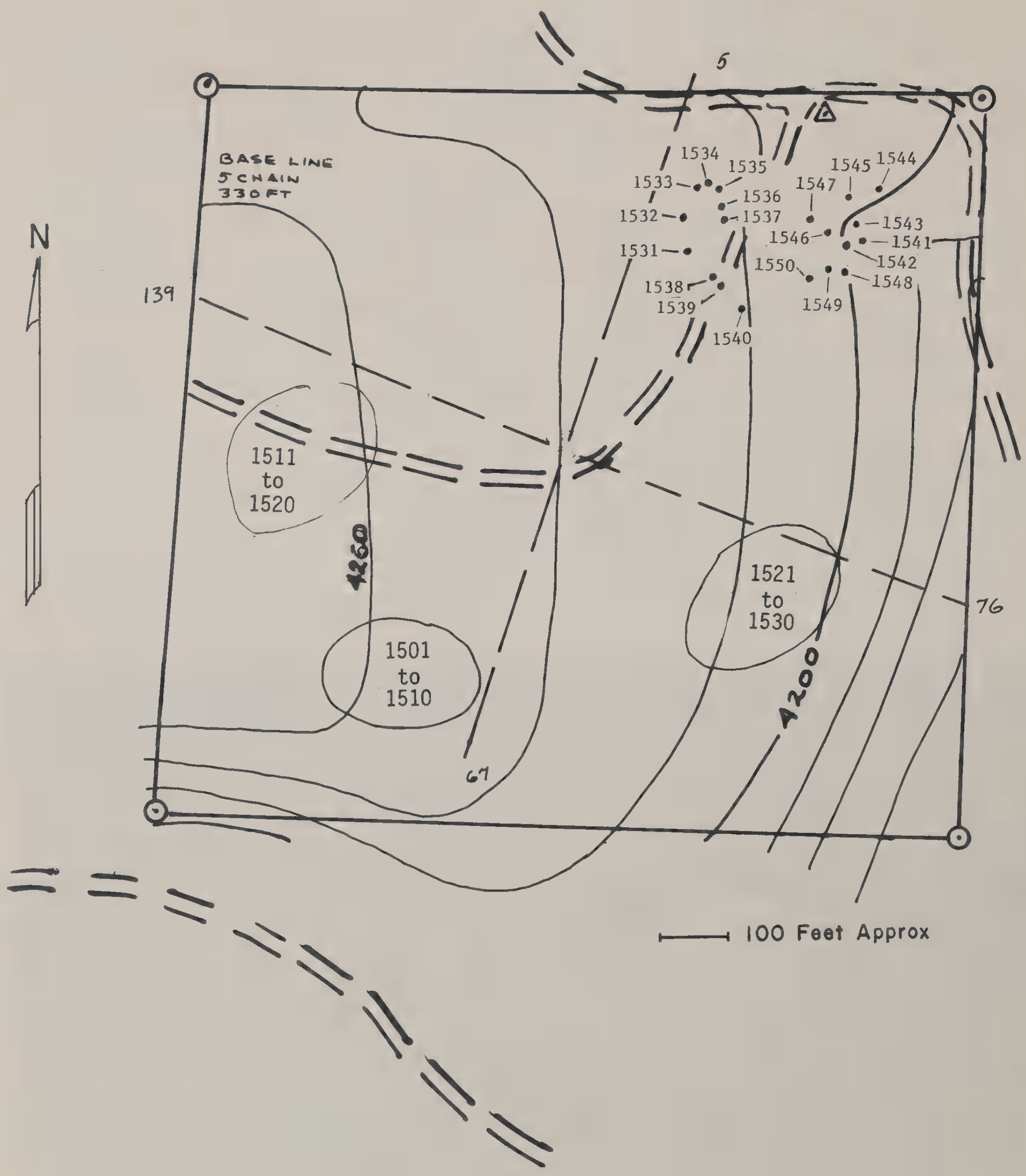


Figure 30. Aerial Photo Upper Blodgett - Trial B-2-5



SOUTH BEAR

LEGEND

Contour (ft)

Sample Line - Cross Configuration

Meteorological Station

Cluster Sampling

Sample Tree - Number

Plot Corner

Figure 31. Plot Diagram South Bear Creek - Trial B-2-6

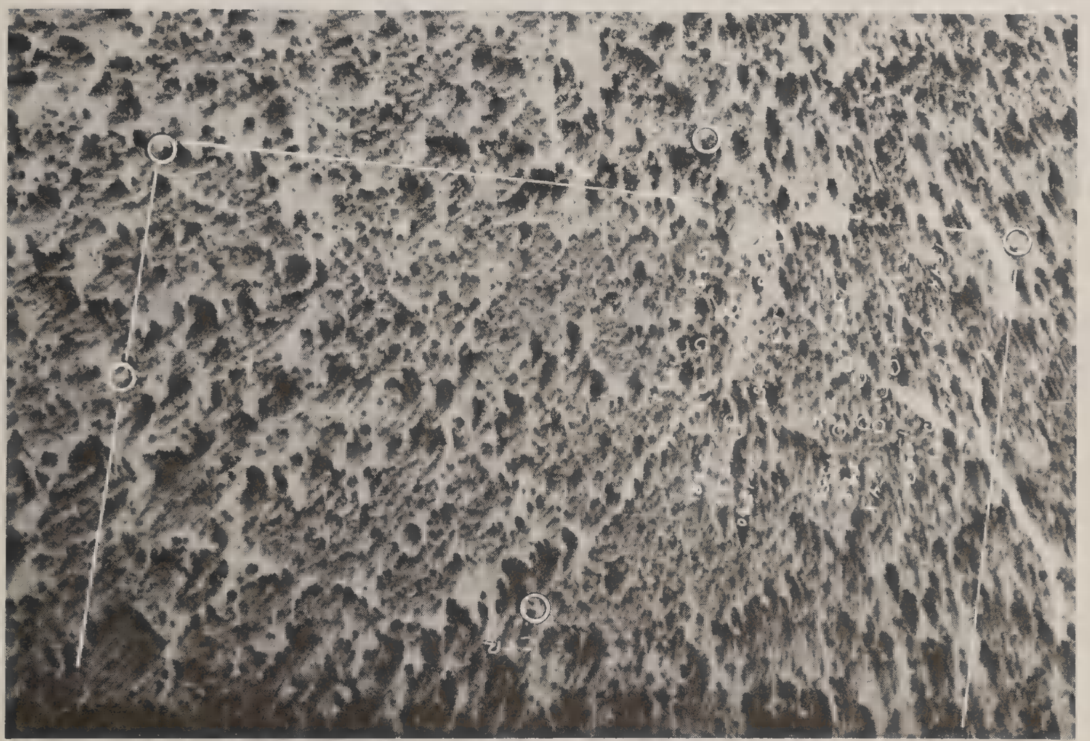


Figure 32. Aerial Photo South Bear Creek - Trial B-2-6

1.8 SAMPLING

Spray sampling was conducted with the printflex deposition card. The printflex card (6 5/8 by 8 5/8 inches) has been used at Dugway Proving Ground for several years. The deposition card, which detects dyed sprays, and predyed oil-sensitive card, which detects undyed oil sprays, are commonly used in aerial spray operations. Cards have proved to be a reliable and simple method for detecting spray coverage and spray concentrations, and for studying the atomization of spray systems. The card is considered unsuitable for sampling small droplets (less than 40 micrometers in diameter) unless special dyes, tracers, or other techniques are used to increase contrast and detection of the drops or stains. Experience gained at Dugway Proving Ground has indicated that the spray must contain a sufficient amount of dye to record a dark stain on the white detector cards to insure adequate assessment.

Four separate sampling methods were used for detection of the deposited spray and for study of spray behavior. Positioning of the cards within the plots was as follows:

a. Beneath trees (inner and outer rings)

b. Cross configuration bisecting center of plot

c. Open areas

d. Cross extensions beyond plot borders

Sampling positions a, b and c are illustrated on the field sampling diagrams in Figures 33 and 34. Figure 35 shows the deposition card arrangement beneath the trees.

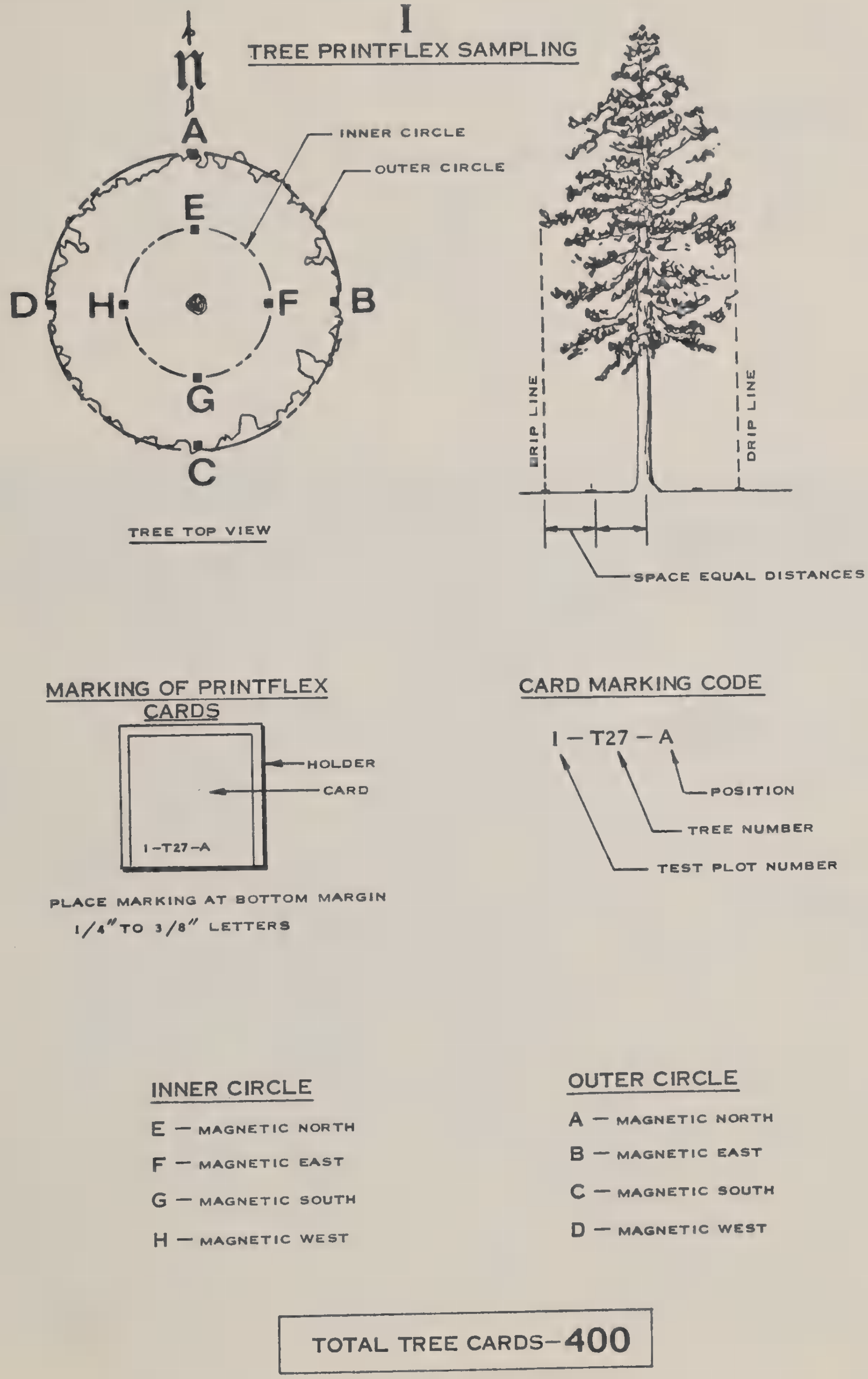


Figure 33. Tree Printflex Card Sampling

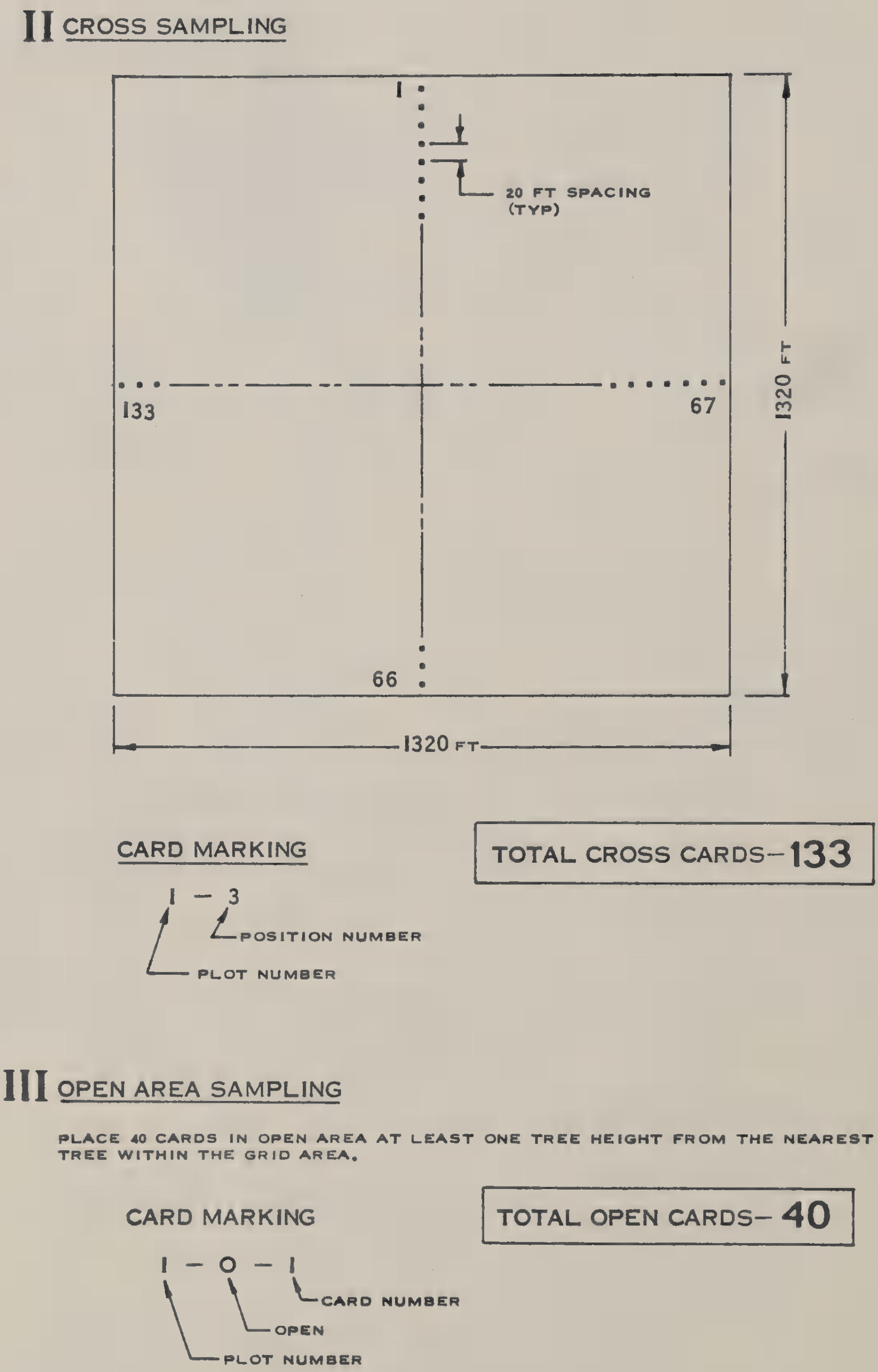


Figure 34. Cross Sampling and Open-Area Sampling with Printflex Cards

Figure 35. Deposition Sample Cards Placed at Tree Drip Line (Outer Ring) and Midway Between Drip Line and Trunk (Inner Ring)

To provide compatibility with the computer program, deposition cards for under-the-tree samples were assigned numbers as follows:

A-1 outer circle magnetic north

B-2 outer circle magnetic east

C-3 outer circle magnetic south

D-4 outer circle magnetic west

E-5 inner circle magnetic north

F-6 inner circle magnetic east

G-7 inner circle magnetic south

H-8 inner circle magnetic west

Cross-sampling lines were extended beyond the periphery of the plot to detect qualitatively the amount of material that drifted beyond the plot border.

The spray droplets on the printflex cards were counted at the Los Alamos Scientific Laboratory, New Mexico, on the Quantimet 720 image analyzer. The data on computer punch cards were delivered to Dugway Proving Ground. The computer program, written in FORTRAN V, was conducted on a Univac 1108 terminal computer system at Dugway Proving Ground.

1.9 METEOROLOGICAL INSTRUMENTATION

Atmospheric conditions were monitored and recorded at or near each test plot during each trial. Measurements were taken for surface observations, vertical temperature profiles to the top of the canopy, and wind speed and direction at the 2-meter level (Figure 36).

Figure 36. Two - Meter Meteorological Station for Measuring and Recording Wind Speed and Wind Direction

1.10 RESULTS AND DISCUSSION

Recoveries of the total material sprayed ranged from 20 to 50 percent for the Zectran trials and 50 to 75 percent for the Bt. trials. The remainder of the material sprayed was lost through evaporation, drift, or impaction on foliage. The mathematical predictions made prior to the test were reasonably accurate in predicting downwind buildup of deposited material during successive swaths. The predictions were used for planning helicopter spray offsetting to counteract the effects of terrain slope, wind direction, and wind velocity to insure maximum deposition of the spray on the target. Downwind buildup of the spray was significant.

The average mass recoveries (gallons per acre) and the vmd of the spray, based upon the different placement of deposition samplers, were as follows:

Mass Recovery and vmd Summary

Sampler Placement	Zectran Trials		Bt. Trials	
	gal/acre	vmd (μm)	gal/acre	vmd (μm)
Sample Tree				
Outer Ring	0.295	290	-	-
Inner Ring	0.250	278	0.179	283
Open	0.396	293	0.570	312
Cross	0.296	282	0.414	318
Drift	0.185	246	0.179	269

Note: Zectran was applied at the rate of 1 gallon per acre. The Bt. was applied at the rate of 2 gallons per acre.

The droplets tended to penetrate the canopy at some point downwind from the swath. The larger droplets were less efficient than the smaller droplets in penetrating to the ground.

The use of spray deposition cards had a significant psychological impact upon the helicopter pilot. Realizing that the spray operation was being monitored on the ground, the pilot made an extra effort to apply the spray material evenly and at the specified rate. However, helicopter swath spraying in forests is imprecise even under optimum conditions. It is essential that the pilot be part of the project team, that he attend all planning meetings, and that he be thoroughly familiar with the test site. The pilot's input can assist the project officer in planning the location of spray plots, boundaries, sample trees, etc.

The meteorological effect of the sun's rays upon the slope was dramatic. At sunrise (when the rays hit the slopes) the downslope or drainage winds were affected within minutes. The wind became disorganized and variable. Until the upslope wind regime developed it was impossible to predict the speed or direction of the wind during the transition period.

The deposition sampling methods used in the test were considered satisfactory. The cross-sampling configuration provided an immediate indication of spray coverage in the field. The average recoveries as calculated from the cross cards provided a quantitative account of the total amount of spray material deposited within the spray area. The cardinal-direction method of sampling gave an average deposi-

tion at each designated sample tree - an average which was generally lower than the recoveries in the open. There was no significant difference between recoveries in the outer sampling ring and in the inner sampling ring in the Zectran trials. The average mass recovery for the outer ring was 0.295 gallon per acre, and 0.250 gallon per acre for the inner ring.

Oil red dye was considered unsatisfactory for field operational use on large-scale spray projects. Several hours were required to mix the dye into solution. After agitation, some of the dye settled out and accumulated in the bottom of the spray tank. In recirculatory spray systems, the sediment is introduced into the circulation, causing nozzle plugging. Under most field conditions adequate agitation equipment will not be available. To achieve a red stain (on white deposition cards) dark enough for machine counting, DuPont oil red dye must be mixed at a concentration approximating the saturation level (1 percent) in kerosene or Number 2 fuel oil.

1.11 RECOMMENDATIONS

It is recommended that:

a. An oil-soluble dye be selected and evaluated. The dye must be easy to mix in the field, and must provide a good contrast on white deposition cards. The use of DuPont oil red dye should be discontinued for field use.

b. Studies be conducted to determine the optimum droplet size required for deposition and impaction upon foliage and upon insects under typical spray conditions.

c. Aircraft pilots be made part of the operational spray team, attend all operational meetings and be thoroughly briefed prior to each spray mission.

d. Deposition cards be placed at each cardinal point at the drip line of the selected tree when conducting spray recovery and insect mortality studies.

e. Mathematical prediction modeling be provided to assist in planning and conducting spray operations. Models will assist in predicting spray drift, thus increasing the efficiency of the project.

f. Studies be conducted to evaluate effects of temperature inversion layers within the forest, and the effects of inversion conditions upon spray-droplet behavior.

g. A method be developed to measure wind speed above the canopy and to the release height. This is necessary to quantify spray drift and to maximize spray deposit within the spray area.

h. A sampler be developed and/or evaluated to quantitatively measure spray drift downwind from spray areas.

i. Deposition samplers, used to obtain a representative spray recovery sample in an open area, be positioned at least three tree heights from the nearest tree.

SECTION 2. TEST RESULTS

2.1 TASK 1. METEOROLOGY

2.1.1 Objective

The objective of Task 1 was to obtain meteorological data at the test plot during spray operations.

2.1.2 Method

The following meteorological measurements were made at 10 of 12 test plots.

a. Vertical temperature intervals from surface to 150 feet. Soundings were made during trials at Mill Creek, Smith Creek, Big Creek, West Sweeney Creek, and South Bear Creek.

b. Wind speed and direction at the 2-meter level measured continuously during each trial.

c. Temperature and relative humidity at the 2-meter level at the start of spray operations.

d. Estimates of cloud cover.

2.1.3 Results

An index by figure and table number is contained in Table 5.

The results of meteorological measurements are presented in Tables 6 through 24 and in Figures 37 through 45. These data are presented in the order in which the trials were conducted.

2.1.4 Discussion

The meteorological data are provided for mathematical modeling, for future analyses of the test data, and for planning of future opera-

tions. No attempt has been made at this time to analyze the total effects of the meteorological conditions on the results obtained. These analyses, however, should be accomplished.

Sunrise and sunset times are provided (Table 25) to assist in planning future operations in the vicinity of Missoula, Montana. Visibility will permit conduct of spray operations from 30 minutes before sunrise to 30 minutes after sunset.

Drainage (downslope) winds began soon after sunset and persisted until sunrise when valley (upslope) winds developed. During the Bitterroot Valley trials the drainage winds became disorganized when the sun's rays hit the east-facing slopes; within minutes, upslope winds developed. This occurrence was relatively easy to predict.

An examination of daytime temperature profile data shows that the upper part of the forest became warmer relative to the ground and air above the forest. This resulted in an inversion layer within the forest which may have influenced the penetration of aerosols and small droplets into the canopy. These effects are not clearly understood. Limited resources (personnel and equipment) precluded the recording of sufficient measurements to determine the effects of temperature inversions within the forest and the influence of these inversions upon spray behavior. It is known that the smaller the spray droplets, the greater is the influence of temperature layers (horizontal) and temperature profile (vertical) boundaries. When drift is a consideration (in most cases it is a major consideration), the temperature profile within the spray area should be measured and the results interpreted by an experienced meteorologist.

Table 26 lists the average canopy height for each plot and the estimate of the maximum foliage mass of the forest canopy. These heights were plotted on the temperature profile figures. In several instances an inversion layer occurred at the height which had been estimated to be the maximum foliage mass of the forest. Successive temperature probes within the forest demonstrated a weakening of the inversion, with a subsequent development of neutral to lapse conditions.

Table 5. Index to Meteorological Data

Figure	Table	Trial	Site	Date 1973	Data
37		Z-1-1	Mill Creek	4 Jun	Vertical Temperature
	6	Z-1-1	Mill Creek	4 Jun	Vertical Temperature
	7	Z-1-1	Mill Creek	4 Jun	Surface Observation
	8	Z-1-1	Mill Creek	4 Jun	Wind Data
	9	Z-1-2	North Bear	4 Jun	Wind Data
38		Z-1-3	Smith Creek	4 Jun	Vertical Temperature
	10	Z-1-3	Smith Creek	4 Jun	Vertical Temperature
	11	Z-1-3	Smith Creek	4 Jun	Surface Observation
	12	Z-1-3	Smith Creek	4 Jun	Wind Data
	13	Z-2-4	Canyon Creek	5 Jun	Wind Data
	14	Z-2-4	Canyon Creek	5 Jun	Surface Observation
39		Z-2-6	Big Creek	5 Jun	Vertical Temperature
40		Z-2-6	Big Creek	5 Jun	Vertical Temperature
	15	Z-2-6	Big Creek	5 Jun	Vertical Temperature
	16	Z-2-6	Big Creek	5 Jun	Wind Data
	17	Z-2-6	Big Creek	5 Jun	Surface Observation
	18	B-1-1	Gash Creek	19 Jun	Wind Data
	19	B-1-2	East Sweeney	19 Jun	Wind Data
41		B-1-3	West Sweeney	19 Jun	Vertical Temperature
42		B-1-3	West Sweeney	19 Jun	Vertical Temperature
43		B-1-3	West Sweeney	19 Jun	Vertical Temperature
	20	B-1-3	West Sweeney	19 Jun	Wind Data
	21	B-1-3	West Sweeney	19 Jun	Surface Observation
	22	B-2-4	Sawdust Gulch	20 Jun	Wind Data
44		B-2-6	South Bear	20 Jun	Vertical Temperature
45		B-2-6	South Bear	20 Jun	Vertical Temperature
	23	B-2-6	South Bear	20 Jun	Wind Data
	24	B-2-6	South Bear	20 Jun	Surface Observation

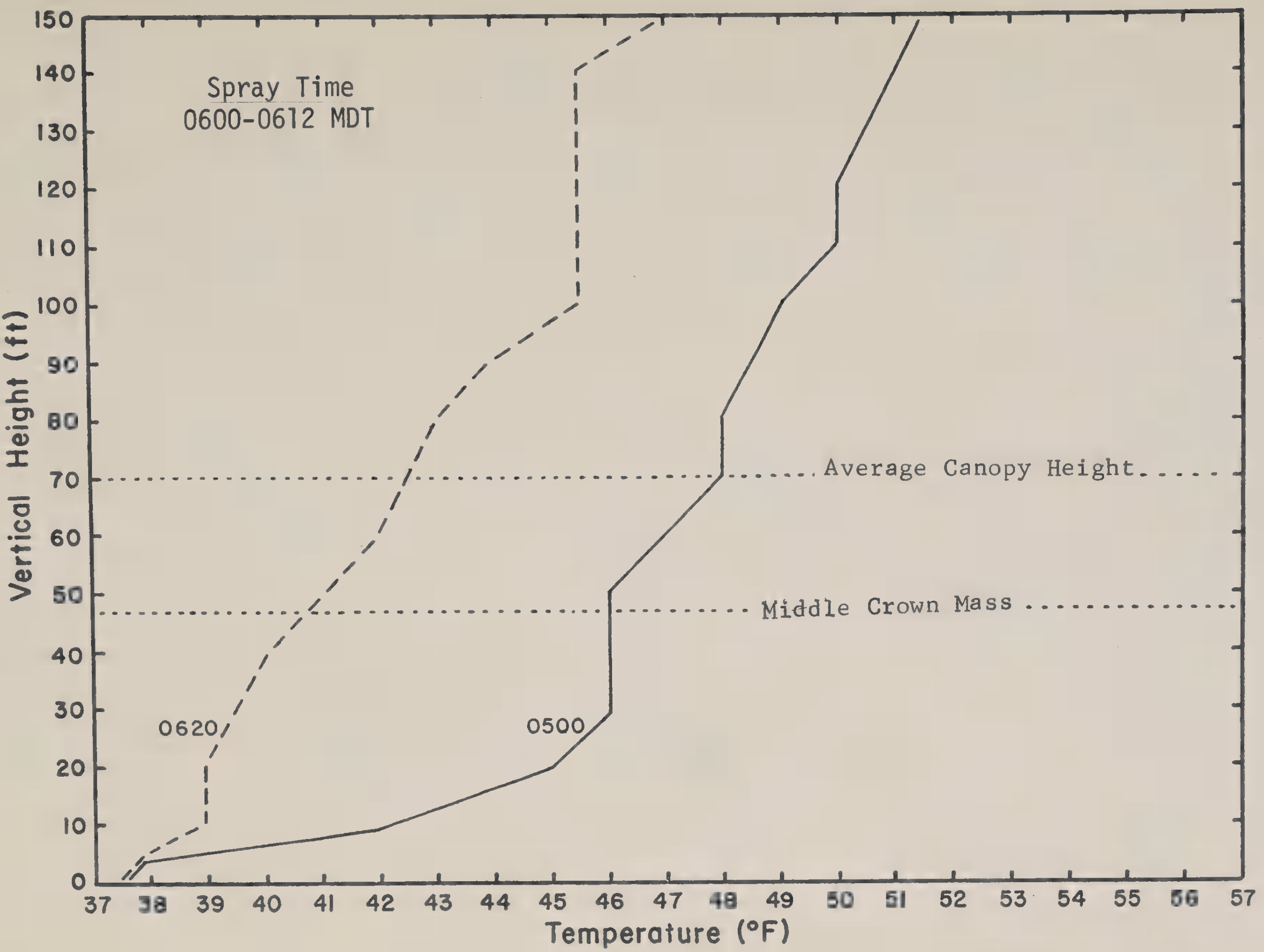


Figure 37. Vertical Temperature Profile - Mill Creek, 4 June 1973

Table 6. Air Stability Conditions - Mill Creek, 4 June 1973

Swath	Time (MDT)	Temperature Gradient Surface to Height Indicated (F^o)				
		10 ft	25 ft	50 ft	100 ft	150 ft
1	0500	4.5	8.0	8.5	11.5	14.0
2	0620	1.5	2.0	3.5	8.0	9.5

Table 7. Surface Meteorological Data - Mill Creek, 4 June 1973

Time	(MDT)	0600
Wind Speed	(mph)	0.5
Wind Direction	(deg Mag)	192
Sky Cover	(pct)	0
Visibility	(mi)	+ 50
Temperature	(^oF)	37.4
Wet Bulb	(^oF)	30.8
Relative Humidity	(pct)	49
Weather		clear

Table 8. Wind Data at 2-Meter Level - Mill Creek, 4 June 1973

Time (MDT)	Wind Speed (mph)			Wind Direction (deg)		
	Mean	Max	Min	Mean	Max	Min
0555-0600	0.6	1.0	<0.5	180	235	125
0600-0601	<0.5	no range		192	no range	
0601-0602	0.5	1.0	<0.5	035	050	020
0602-0603	0.8	no range		330	360	315
0603-0604	0.8	no range		310	no range	
0604-0605	<0.5	no range		220	no range	
0605-0606	<0.5	no range		135	140	110
0606-0607	0.7	no range		105	no range	
0607-0608	<0.5	no range		105	no range	
0608-0609	0.5	1.0	<0.5	280	285	275
0609-0610	0.7	1.0	0.5	290	300	285
0610-0611	0.5	no range		270	285	260
0611-0612	0.7	1.0	0.5	315	025	270
0612-0613	0.5	1.0	0.2	055	065	025
0613-0614	1.0	1.5	0.5	090	no range	
0614-0615	1.0	1.5	0.5	090	no range	
0615-0616	1.0	1.5	0.5	225	250	200
0616-0617	1.0	1.5	0.5	205	220	200
0617-0618	1.0	no range		225	no range	
0618-0619	1.0	no range		225	no range	
0619-0620	<0.5	no range		225	no range	
0620-0621	<0.5	no range		225	no range	

Table 9. Wind Data at 2-Meter Level - North Bear Creek, 4 June 1973

Time (MDT)	Wind Speed (mph)			Wind Direction (deg)		
	Mean	Max	Min	Mean	Max	Min
0530-0611	0.5	1.0	<0.5	225	270	180
0600-0630	0.5	1.0	<0.5	245	315	170
0630-0700	0.5	2.0	<0.5	225	270	150

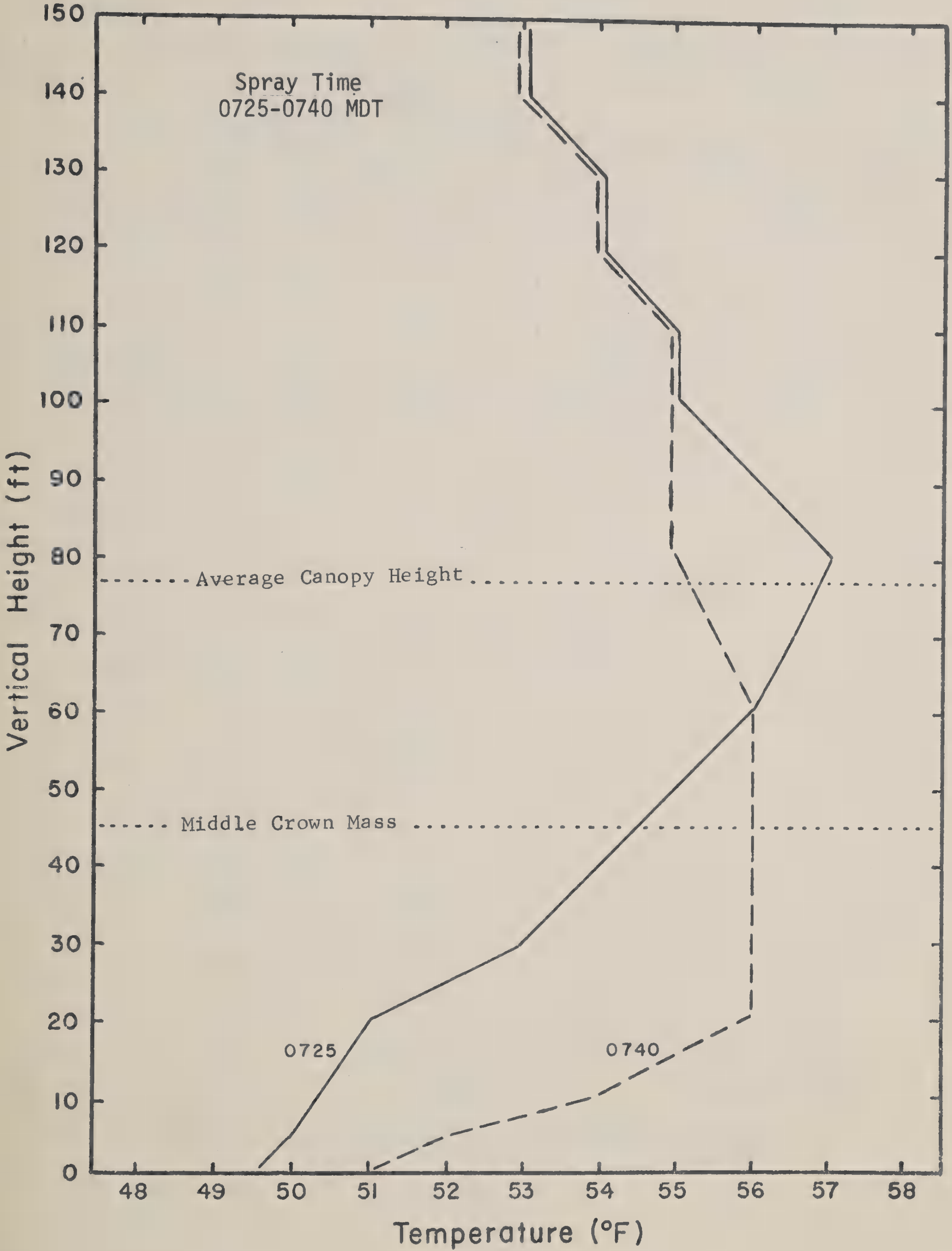


Figure 38. Vertical Temperature Profile - Smith Creek
4 June 1973

Table 10. Air Stability Conditions - Smith Creek, 4 June 1973

Swath	Time (MDT)	Temperature Gradient Surface to Height Indicated (F^o)				
		10 ft	25 ft	50 ft	100 ft	150 ft
1	0725	1.0	2.5	2.5	5.5	3.5
2	0740	3.0	5.0	5.0	4.0	2.0

Note: Inversion conditions existed at beginning of spray operations. Neutral to lapse conditions developed prior to completion of spraying.

Table 11. Surface Meteorological Data - Smith Creek, 4 June 1973

Time	(MDT)	0725
Wind Speed	(mph)	2.0
Wind Direction	(deg Mag)	335
Sky Cover	(pct)	0
Visibility	(mi)	+ 50
Temperature	(^oF)	49.5
Wet Bulb	(^oF)	41.5
Relative Humidity	(pct)	50
Weather		Clear

Table 12. Wind Data at 2-Meter Level - Smith Creek, 4 June 1973

Time (MDT)	Wind Speed (mph)			Wind Direction (deg)		
	Mean	Max	Min	Mean	Max	Min
0715-0725	2.0	3.5	1.5	335	005	300
0725-0735	2.0	3.0	1.0	025	060	010
0735-0740	1.5	2.0	1.0	045	070	020
0740-0741	1.5	2.0	1.0	180	190	135
0741-0742	1.5	2.0	1.0	135	150	125
0742-0743	1.5	2.0	1.0	120	130	110
0743-0744	2.0	3.0	1.0	125	135	115
0744-0745	1.5	2.0	1.0	145	155	130
0745-0746	3.0	4.0	1.5	145	150	135
0746-0747	3.5	4.5	2.5	160	165	155
0747-0748	2.5	3.0	2.0	150	160	145
0748-0749	3.0	3.5	2.5	150	170	145
0749-0750	3.5	4.0	2.5	145	165	120
0750-0800	2.5	5.0	1.5	135	165	115

Table 13. Wind Data at 2-Meter Level - Canyon Creek, 5 June 1973

Time (MDT)	Wind Speed (mph)			Wind Direction (deg)		
	Mean	Max	Min	Mean	Max	Min
0500-0530	3.0	3.5	2.5	295	315	270
0530-0600	2.5	3.5	1.5	290	300	270
0620-0621	3.0	3.5	2.5	265	270	260
0622-0623	2.5	no range		280	290	260
0623-0624	2.5	2.6	1.8	295	300	290
0624-0625	2.5	3.0	2.5	305	310	300
0625-0626	2.7	3.0	2.5	305	310	300
0626-0627	2.5	3.0	2.0	312	315	310
0627-0628	2.0	2.5	1.5	320	325	315
0628-0629	2.5	2.7	2.0	310	315	305
0629-0630	2.0	2.5	1.5	300	330	260
0630-0631	2.5	3.0	1.5	255	265	250
0631-0632	2.2	2.5	2.0	255	265	250
0632-0633	2.2	2.5	2.0	275	285	270
0633-0634	2.0	2.5	1.8	275	285	265
0634-0635	1.5	2.0	1.0	262	no range	
0635-0636	1.5	no range		270	300	260
0636-0637	2.0	2.5	1.5	302	305	300
0637-0638	2.0	2.2	1.8	290	295	280
0638-0639	1.5	no range		285	no range	

Table 14. Surface Meteorological Data - Canyon Creek, 5 June 1973

Time	(MDT)	0620
Wind Speed	(mph)	3.0
Wind Direction	(deg Mag)	265
Sky Cover	(pct)	0
Visibility	(mi)	+ 50
Temperature	(^{o}F)	49.9
Wet Bulb	(^{o}F)	39.8
Relative Humidity	(pct)	40
Weather		Clear

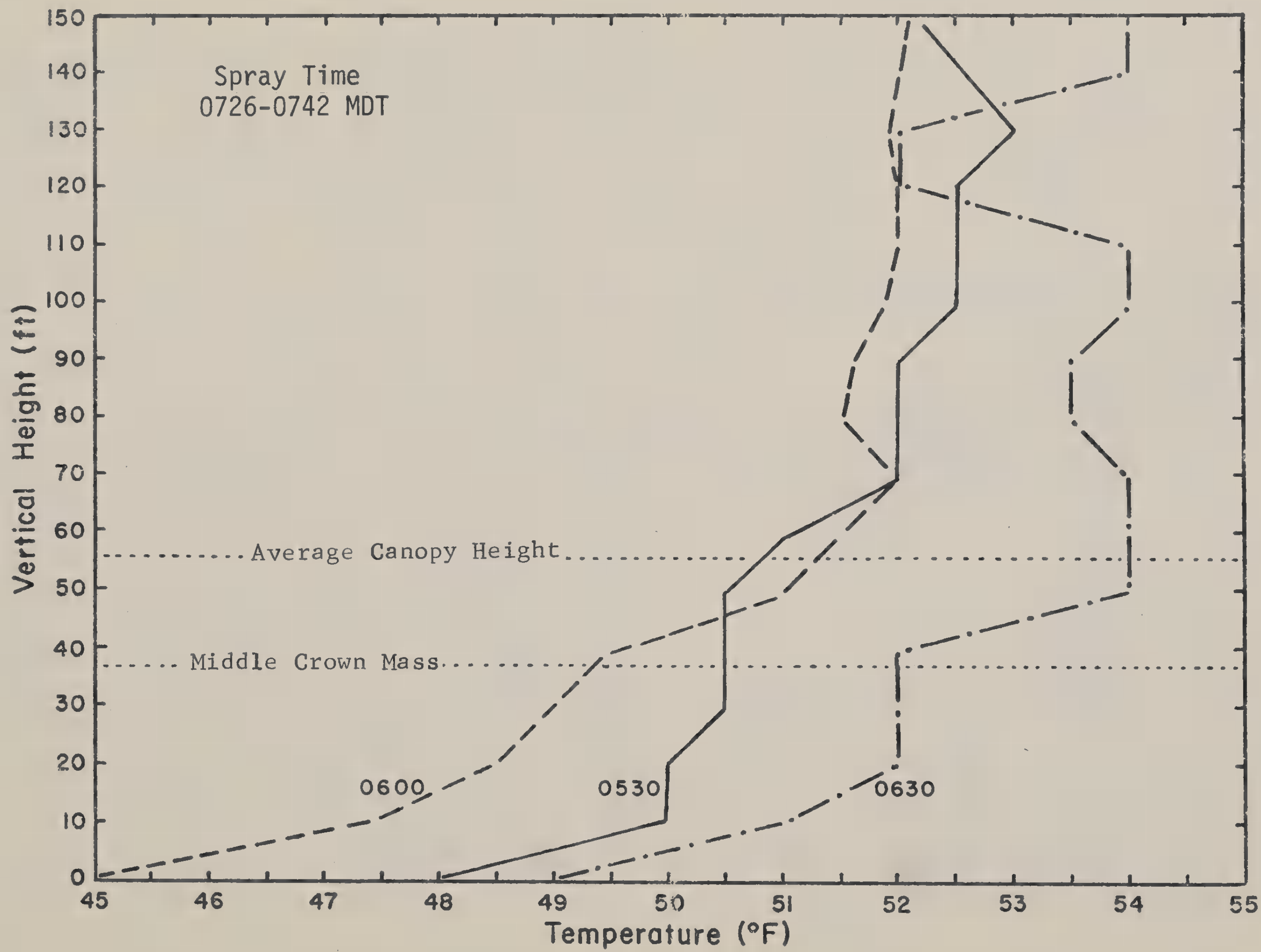


Figure 39. Vertical Temperature Profile - Big Creek, 5 June 1973

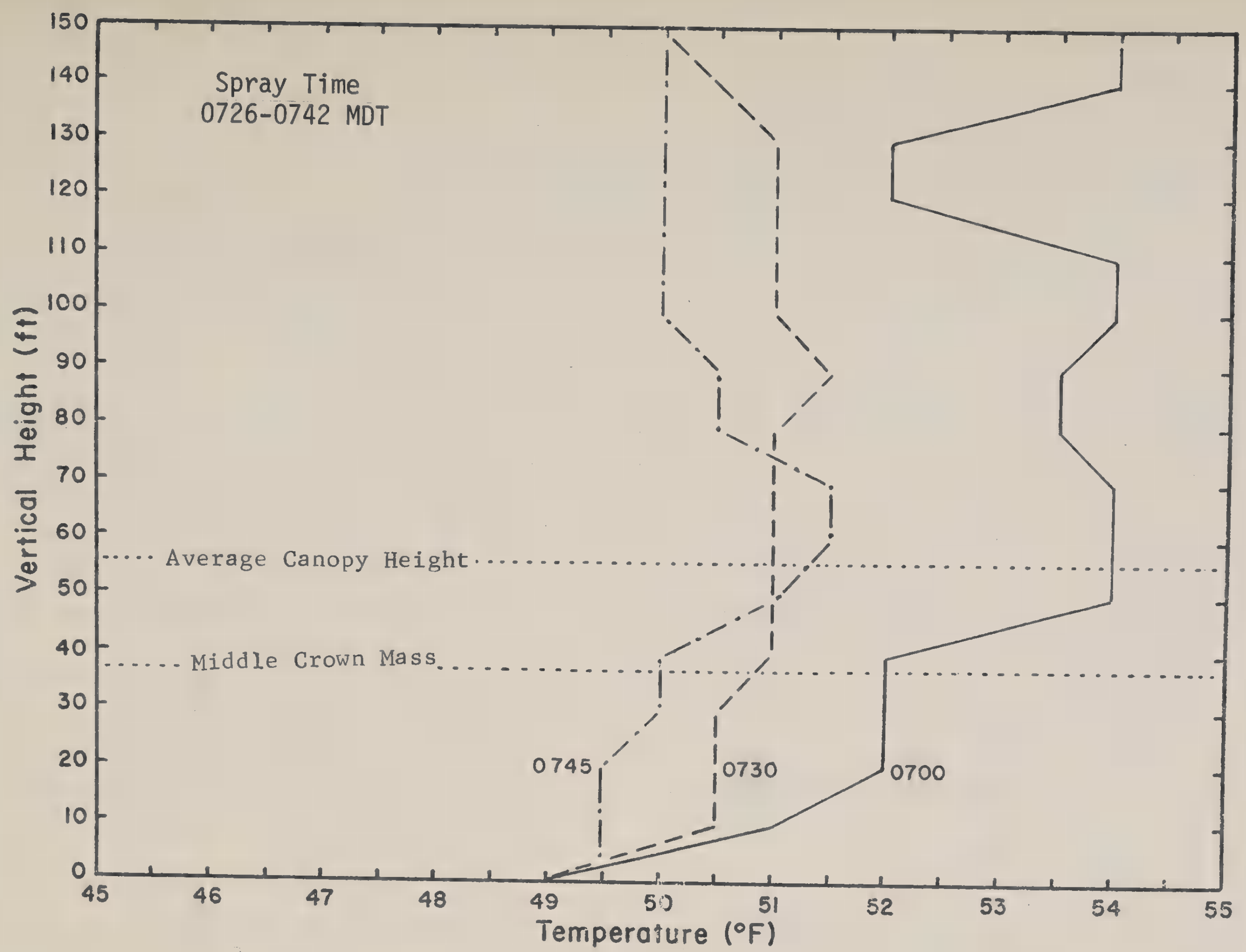


Figure 40. Vertical Temperature Profile - Big Creek, 5 June 1973

Table 15. Air Stability Conditions - Big Creek, 5 June 1973

Swath	Time (MDT)	Temperature Gradient Surface to Height Indicated (F^o)				
		10 ft	25 ft	50 ft	100 ft	150 ft
1	0530	2.5	2.2	2.5	4.5	4.0
2	0600	2.5	4.0	6.0	6.8	7.2
3	0630	1.5	3.0	4.0	8.0	6.0
4	----	2.0	3.0	5.0	5.0	7.0
5	----	1.5	1.5	2.0	2.0	1.0
6	----	0.0	0.2	1.5	0.5	0.5

Table 16. Wind Data at 2-Meter Level - Big Creek, 5 June 1973

Time (MDT)	Wind Speed (mph)			Wind Direction (deg)		
	Mean	Max	Min	Mean	Max	Min
0500-0530	3.5	4.0	2.5	290	300	280
0530-0600	2.5	3.0	1.9	270	290	250
0725-0726	3.0	3.5	2.5	170	175	165
0726-0727	3.0	3.5	2.5	170	175	150
1727-0728	5.0	6.0	3.5	155	165	130
0728-0729	4.0	5.0	2.5	180	200	135
0729-0730	2.5	3.0	2.0	225	240	205
0730-0731	2.5	2.6	2.0	225	240	215
0731-0732	2.0	2.5	1.5	215	225	200
0732-0733	2.5	3.0	2.0	185	190	180
0733-0734	2.5	3.0	2.0	180	185	155
0734-0735	2.5	3.5	2.4	180	190	165
0735-0736	2.5	3.0	2.0	185	195	180
0736-0737	3.0	3.5	2.5	190	195	180
0737-0738	3.5	4.0	2.5	170	190	160
0738-0739	4.0	4.5	3.0	170	180	160
0739-0740	3.0	3.5	2.5	155	180	145
0740-0741	3.5	4.0	3.0	180	190	170
0741-0742	4.2	4.5	4.0	190	195	185
0742-0743	4.0	4.5	3.5	190	195	185
0743-0744	4.0	4.5	3.5	180	195	170
0744-0745	3.5	4.5	2.5	190	200	180
0745-0815	3.0	4.0	2.5	180	215	165

Table 17. Surface Meteorological Data - Big Creek, 5 June 1973

Time	Wind Speed	Wind Direction	Weather	Visibility	Temp	Wet Bulb	Relative Humidity
(MDT)	(mph)	(deg Mag)		(mi)	(°F)	(°F)	(pct)
0500	2.5	315	Clear	+50	48.0	40.0	50
0600	2.5	270	Clear	+50	48.0	40.0	50
0630	2.5	270	Clear	+50	49.5	41.0	49
0700	1.0	235	Clear	+50	50.0	41.0	46
0730	3.0	135	Clear	+50	52.0	43.0	49
0745	3.0	150	Clear	+50	54.0	44.0	46

Table 18. Wind Data - Gash Creek, 19 June 1973

Time	Wind Speed	Wind Speed Range	Wind Direction	Wind Dir Range
(MDT)	(mph)	(mph)	(deg)	(deg)
0618	1.0	0.5-1.0	285	285-005
0619	0.5	0.5-1.0	005	360-005
0620	<0.5	no range	360	345-360
0621	<0.5	no range	345	315-345
0622	<0.5	no range	315	315-335
0623	0.5	<0.5-1.0	335	335-005
0624	1.0	1.0-2.0	005	005-010
0625	2.0	1.5-2.5	010	275-010
0626	2.0	1.5-2.0	285	285-310
0627	1.5	1.0-3.0	310	280-315
0628	2.5	1.0-2.5	280	280-295
0629	1.0	<0.5-1.0	295	295-320
0630	<0.5	<0.5-1.0	320	265-320
0631	1.5	0.5-1.5	265	265-325
0632	0.5	0.5-1.0	325	295-325

Table 19. Wind Data - East Sweeney Creek, 19 June 1973

Time	Wind Speed	Wind Speed Range	Wind Direction	Wind Dir Range
(MDT)	(mph)	(mph)	(deg)	(deg)
0703	0.5	<0.5-1.0	235	170-235
0704	0.5	<0.5-1.0	210	185-215
0705	1.0	<0.5-1.0	180	165-200
0706	Calm	<0.5-1.0	190	190-215
0707	1.0	<0.5-1.0	215	145-215
0708	1.0	<0.5-1.0	160	150-165
0709	1.0	<0.5-1.0	150	no range
0710	<0.5	no range	150	no range
0711	<0.5	<0.5-1.0	150	150-180
0712	0.5	<0.5-1.0	170	170-190
0713	<0.5	<0.5-1.0	190	190-230
0714	<0.5	<0.5-1.0	220	190-220
0715	0.5	<0.5-1.0	195	140-195

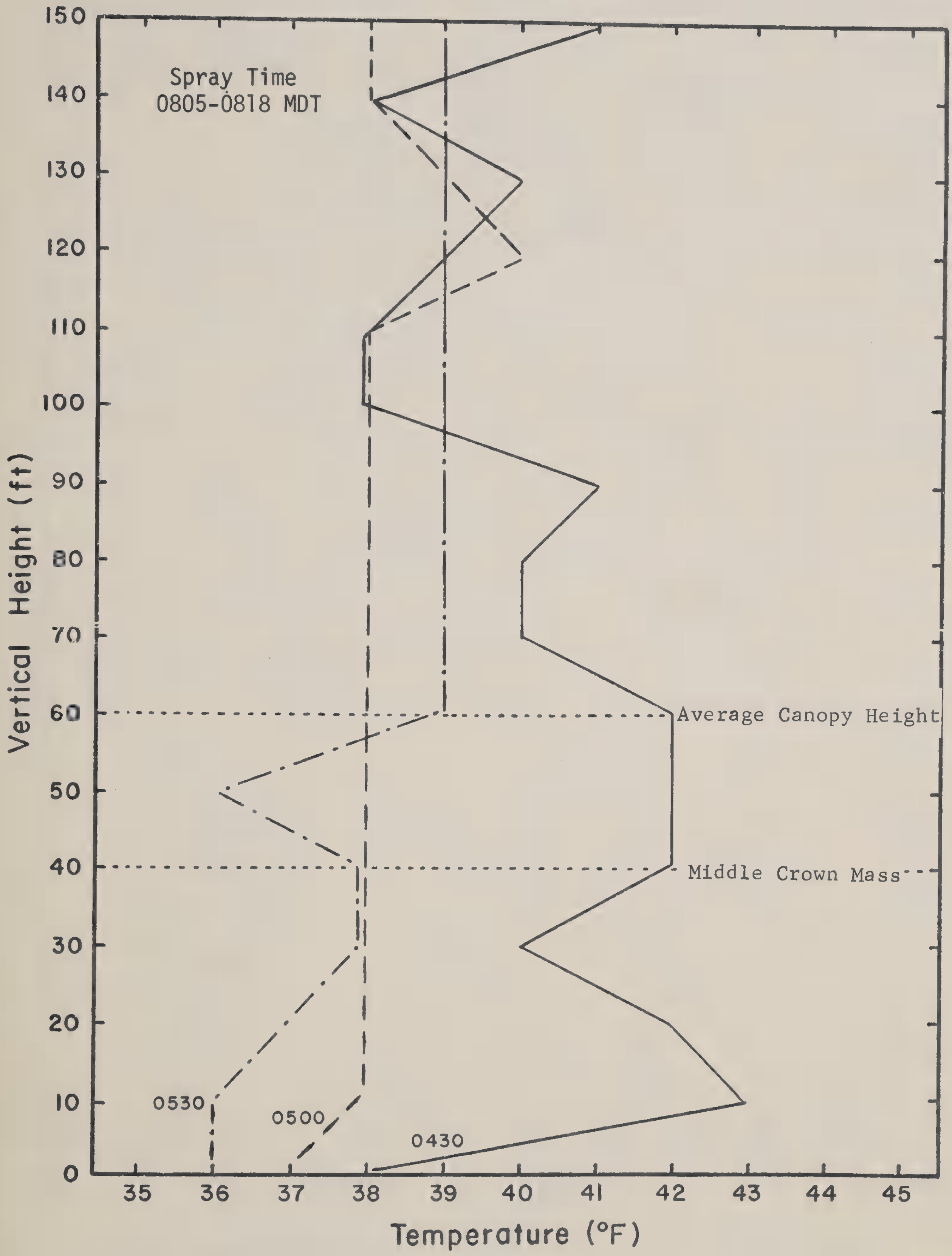


Figure 41. Vertical Temperature Profile - West Sweeney Creek, 19 June 1973

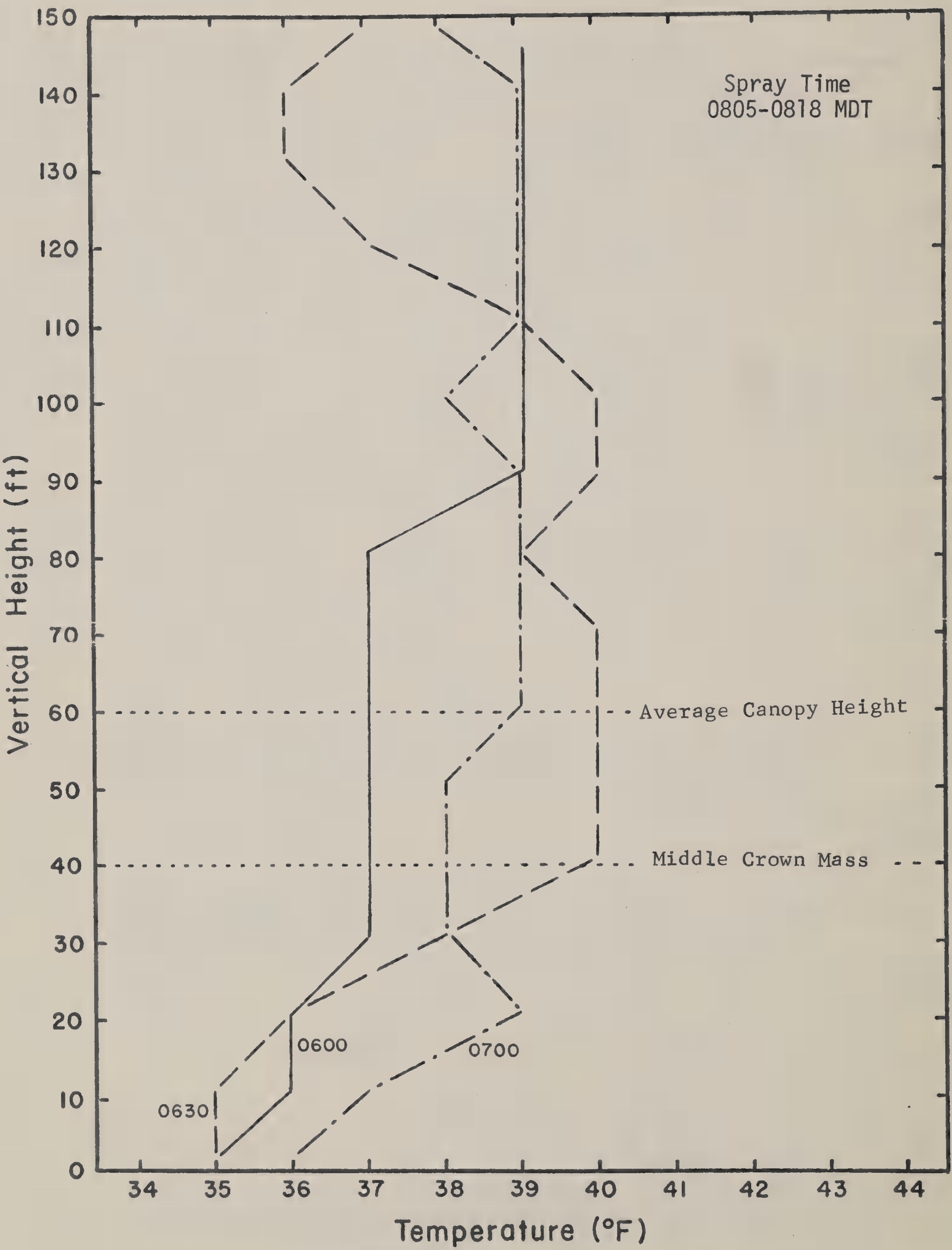


Figure 42. Vertical Temperature Profile - West Sweeney Creek, 19 June 1973

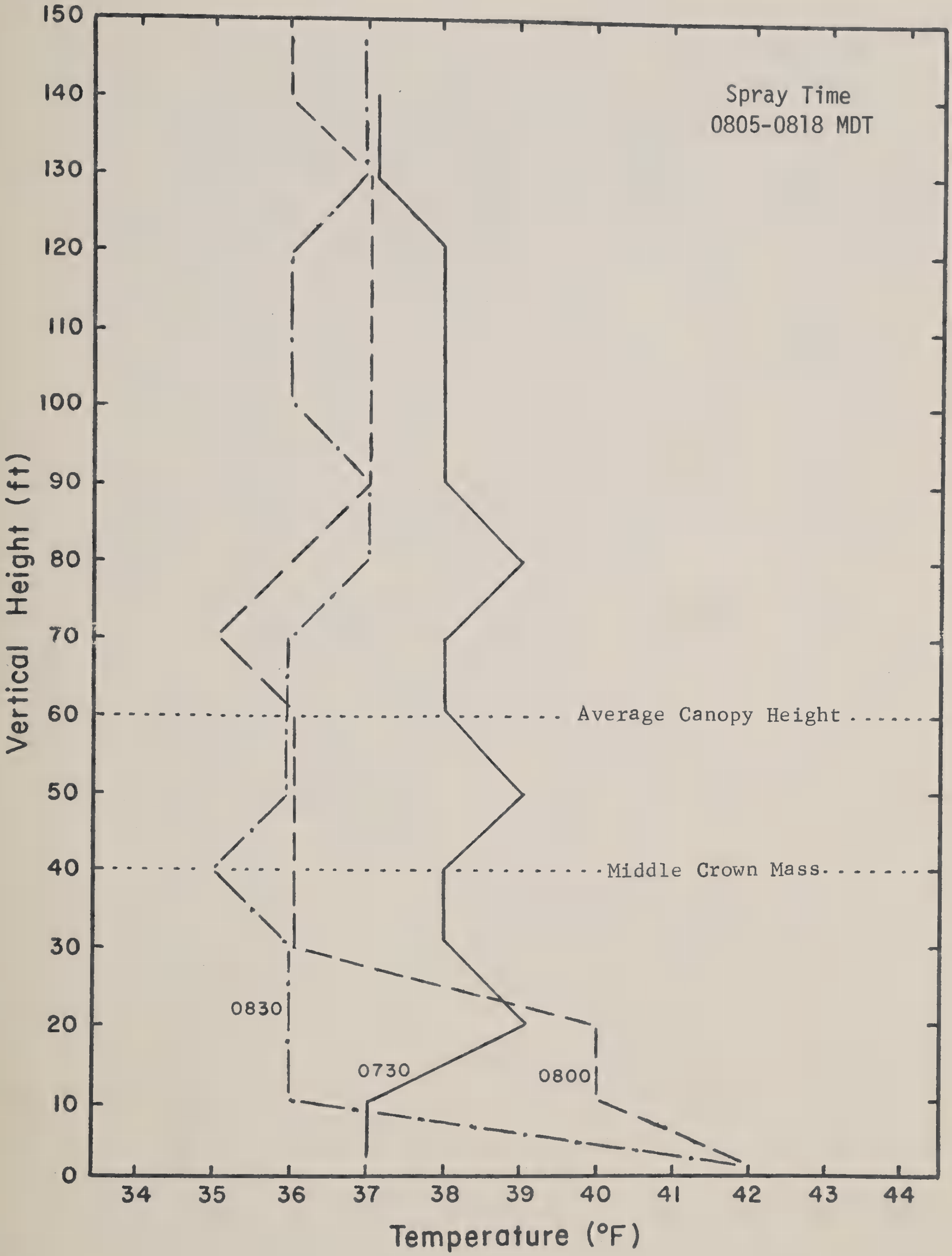


Figure 43. Vertical Temperature Profile - West Sweeney Creek, 19 June 1973

Table 20. Wind Data - West Sweeney Creek, 19 June 1973

Time	Wind Speed	Wind Speed Range	Wind Direction	Wind Dir Range
(MDT)	(mph)	(mph)	(deg)	(deg)
0805	2.0	1.0-2.5	040	040-060
0806	1.5	1.0-2.5	060	060-105
0807	2.0	2.0-3.0	105	080-110
0808	2.5	1.5-3.0	080	050-085
0809	1.5	1.5-4.0	080	075-120
0810	2.5	1.0-2.5	100	040-145
0811	2.5	1.5-2.5	145	130-145
0812	1.5	1.5-2.5	140	100-140
0813	2.5	1.5-3.5	105	100-185
0814	1.5	1.5-2.5	185	115-185
0815	2.5	1.5-2.5	120	105-130
0816	3.5	2.0-3.5	100	075-105
0817	3.5	2.0-3.5	100	075-105
0818	2.5	1.5-2.5	095	070-115

Table 21. Surface Meteorological Data - West Sweeney Creek, 19 June

Time	Temperature	Wet Bulb	Relative Humidity	Dew Point
(MDT)	(^{o}F)	(^{o}F)	(pct)	(^{o}F)
0430	40.2	36.3	70	31
0500	38.2	35.0	75	32
0530	37.6	35.0	80	33
0600	34.8	33.6	91	33
0630	36.3	34.8	88	33
0700	37.5	36.3	91	36
0730	39.0	36.8	84	35
0800	42.2	38.9	76	35
0830	42.4	39.5	80	36

Table 22. Wind Data - Sawdust Gulch, 20 June 1973

Time	Wind Speed	Wind Speed Range	Wind Direction	Wind Dir Range
(MDT)	(mph)	(mph)	(deg)	(deg)
0608	2.5	2.0-2.5	320	320-335
0609	2.0	2.0-2.5	335	335-340
0610	2.0	2.0-2.5	335	335-345
0611	2.5	2.0-2.5	350	335-350
0612	2.5	2.0-2.5	335	320-335
0613	2.0	2.0-2.5	320	320-330
0614	2.0	no range	325	325-335
0615	2.0	no range	325	325-335
0616	2.0	no range	335	320-335
0617	2.0	1.5-2.0	325	325-330
0618	1.5	no range	330	330-340
0619	1.5	1.5-2.0	340	340-350
0620	1.5	1.5-2.5	350	315-350
0621	2.5	1.5-3.0	335	305-335
0622	1.5	1.0-1.5	310	295-310
0623	1.0	1.0-1.5	310	310-320
0624	1.0	1.0-1.5	320	320-320
0625	1.5	no range	320	315-320
0626	1.5	1.0-1.5	315	no range
0627	1.0	no range	315	315-325
0628	1.0	1.0-1.5	325	325-335
0629	1.5	1.5-2.0	335	330-340
0630	1.5	1.0-1.5	340	335-345

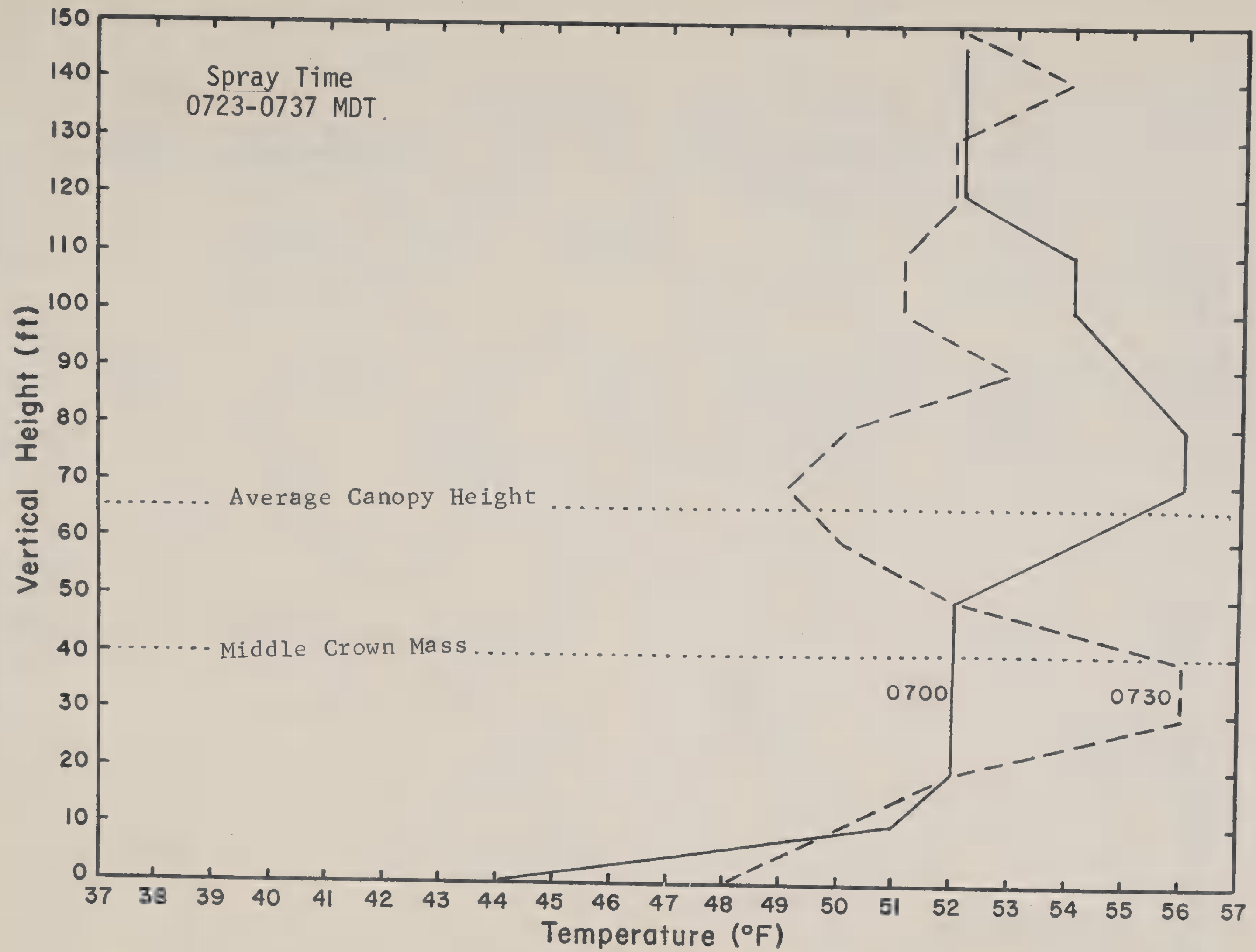


Figure 44. Vertical Temperature Profile - South Bear Creek, 20 June 1973

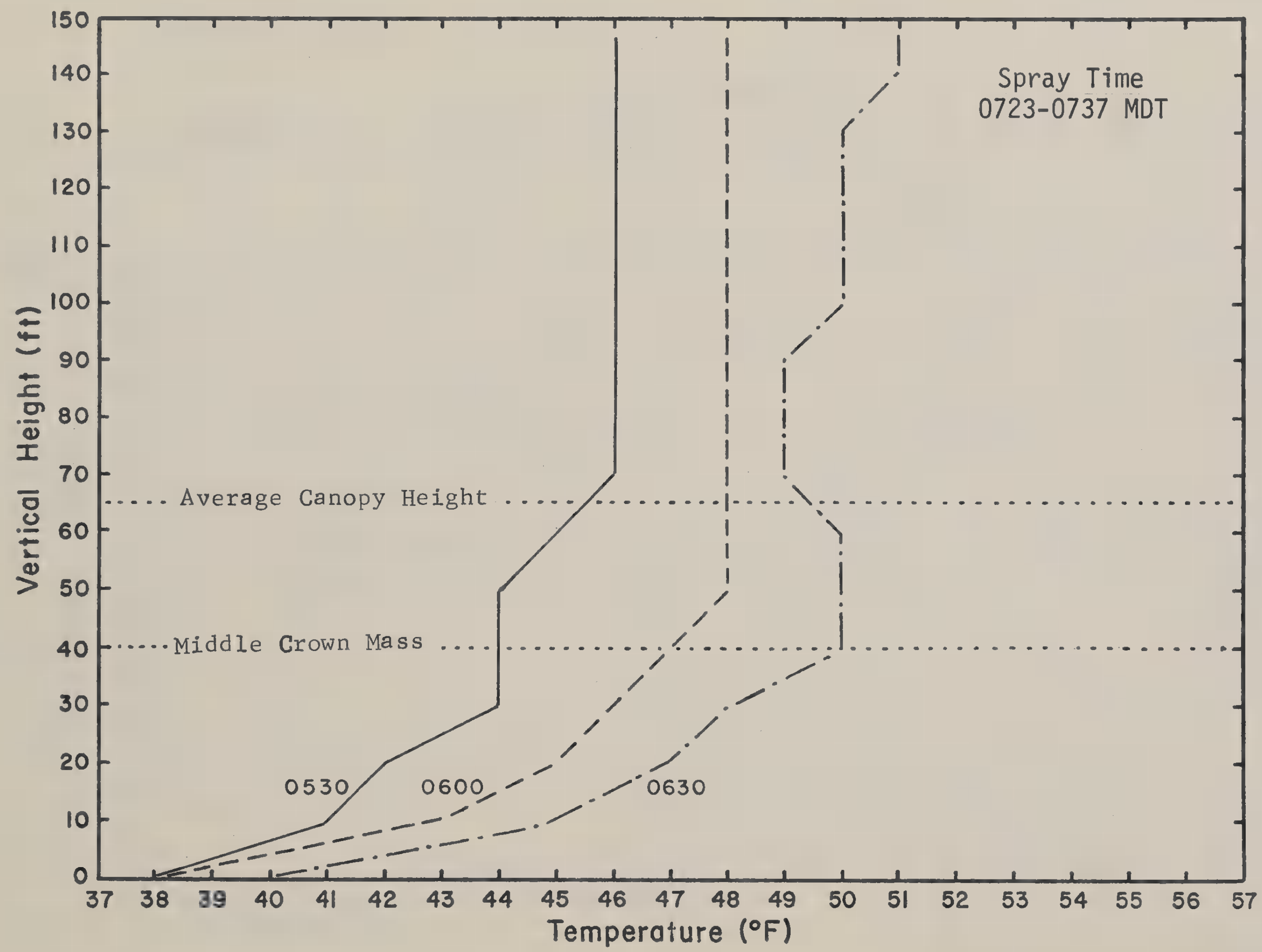


Figure 45. Vertical Temperature Profile - South Bear Creek, 20 June 1973

Table 23. Wind Data - South Bear Creek, 20 June 1973

Time	Wind Speed	Wind Speed Range	Wind Direction	Wind Dir Range
(MDT)	(mph)	(mph)	(deg)	(deg)
0723	<0.5	no range	---	263-352
0724	<0.5	no range	---	no range
0725	2.5	<0.5-2.7	197	135-212
0726	<0.5	no range	---	no range
0727	<0.5	no range	---	225-250
0728	1.0	1.0-2.0	080	080-225
0729	1.0	1.0-2.5	067	040-080
0730	1.0	1.0-2.0	130	065-145
0731	1.0	1.0-2.0	130	065-135
0732	2.0	1.0-2.5	070	070-090
0733	1.0	no range	090	090-130
9734	1.0	<0.5-1.0	125	055-125
0735	0.5	<0.5-1.0	055	320-055
0736	<0.5	no range	---	no range
0737	<0.5	no range	---	no range

Table 24. Surface Meteorological Data - South Bear Creek, 20 June

Time	Temperature	Wet Bulb	Relative Humidity	Dew Point
(MDT)	(°F)	(°F)	(pct)	(°F)
0530	38.0	37.1	92	36
0600	40.1	38.5	89	37
0630	40.1	38.8	90	37
0700	45.8	43.1	85	42
0730	47.9	44.7	80	39

Table 25. Sunrise and Sunset Times
Airport, Missoula, MT

June 1973 (MST)	Sunrise	Sunset
16	0541	2133
17	0541	2133
18	0541	2134
19	0541	2134
20	0541	2134
21	0541	2135
22	0542	2135
23	0542	2135
24	0542	2135
25	0542	2135
26	0543	2135
27	0543	2135
28	0544	2135
29	0544	2135
30	0545	2135

Table 26. Average Canopy Height and Height Estimate of Middle Point of Foliage Mass in the Vertical Profile

Test Plot	Average Height of Canopy	Maximum Foliage Mass [a]
	(ft)	(ft)
Mill Creek	70	47
North Bear Creek	45	30
Smith Creek	67	45
Canyon Creek	60	40
Lower Blodgett Creek	70	47
Big Creek	56	37
Gash Creek	55	37
East Sweeney Creek	60	40
West Sweeney Creek	60	40
Sawdust Creek	55	37
Upper Blodgett Creek	70	47
South Bear Creek	65	43

[a] Estimated 2/3 average canopy height.

2.2 TASK 2. CANOPY PENETRATION

2.2.1 Objective

The objective of Task 2 was to investigate canopy penetration of the chemical and biological insecticidal sprays released over a ponderosa pine forest.

2.2.2 Method

The deposition-card sampling method employed for this task is discussed in Paragraph 1.8. Approximately 40 deposition cards were placed in open areas within the test plot. In theory, the recoveries on these cards represented the amount of material available at the top of the canopy. Cards were also placed beneath selected trees. Thus, with droplet-recovery data from open terrain areas and from beneath the trees, a ratio was constructed to represent the penetration of the spray through the canopy. (A ratio of 1 represented 100 percent penetration of the spray to the ground.) Ratios were established for several droplet size categories and plotted on log paper. This method has been used for several years to evaluate forest spraying.

An attempt was made to position the open-area cards at least 2 to 3 tree heights from the nearest tree to insure that the tree did not filter out any portion of the spray. Large spray droplets (approximately 1,000 micrometer diameter) will generally fall directly downward and will not be intercepted unless a tree is directly in the path of fall. The smaller the droplet, the greater is the influence of air movement on the droplet. This causes a longer settling time and a

greater chance for the droplet to come in contact with a tree. These facts are basic, but an understanding is necessary for planning forest spray projects which involve deposition sampling.

2.2.3 Results

The results of this task are shown in Tables 27 through 38 and in Figures 46 through 81. Penetration ratios were plotted for two sets of data (the drop size plotted was the lower limit of the drop size category). The first ratio shows recoveries from beneath the trees to recoveries in the open. The second ratio shows recoveries from the cross sampling to recoveries in the open. Cross-card data represent recoveries within the forest, and open-area data represent recoveries from cards located in the open areas.

2.2.4 Discussion

Generally it would be expected that the larger the droplet the greater the deposition upon tree foliage (i.e., fewer of the larger drops would be recovered on deposition cards located beneath the tree). This normal pattern was demonstrated on most trials utilizing the *Bt*. spray. The results of the Zectran trials, however, were not as expected. For some trials, the penetration ratios approximated or were greater than one. Consequently, the cross-card data to open-area data were plotted using the rationale that the cross cards were placed more randomly throughout the forest. Examination of the Zectran trial data did not provide an explanation of the unexpected results.

It appears that there are factors affecting the spray cloud which are not understood. A thorough study of the following influencing factors may provide a better understanding of the spray problem.

a. Terrain slope

b. Drift and downslope deposit buildup

c. Sampling bias

d. Spray properties

e. Spray pattern

f. Assessment error

Table 27. Printflex Card Data, Trial Z-1-1, Mill Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
20	0.123	8471	0.250	1766	0.233	5369	0.492	0.932
33	0.165	2917	0.325	586	0.333	1962	0.508	1.025
53	0.777	3257	1.525	677	1.209	1717	0.510	0.793
86	2.640	3516	4.225	591	3.403	1532	0.625	0.805
119	5.354	3129	8.800	540	7.008	1387	0.608	0.796
151	9.420	2811	16.975	532	13.093	1323	0.555	0.771
187	11.239	1996	19.150	357	12.868	774	0.587	0.672
215	23.265	2508	37.200	421	22.085	806	0.625	0.594
259	29.858	1913	44.600	300	22.814	495	0.669	0.512
305	23.444	971	37.250	162	18.186	255	0.629	0.488
348	28.024	734	54.900	151	18.264	162	0.510	0.333
413	14.486	238	31.875	55	5.752	32	0.454	0.180
476	5.654	61	11.475	13	2.465	9	0.493	0.215
547	1.735	13	1.275	1	---	---	1.361	---
609	0.554	3	1.750	1	0.543	1	0.317	0.310

Table 28. Printflex Card Data, Trial Z-1-2, North Bear Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
20	0.757	54454	0.703	4756	0.384	7724	1.077	0.546
33	1.201	22058	1.108	1876	0.696	3588	1.084	0.628
53	3.388	14898	3.568	1458	3.000	3707	0.950	0.841
86	8.276	11535	9.243	1196	7.330	2869	0.895	0.793
119	14.574	8919	17.162	974	13.205	2269	0.849	0.769
151	23.258	7269	26.919	780	17.893	1570	0.864	0.665
187	23.907	4447	26.135	451	17.330	905	0.915	0.663
215	42.030	4745	46.135	483	28.625	907	0.911	0.620
259	46.336	3109	47.243	294	28.723	541	0.981	0.608
305	38.433	1667	44.243	178	22.920	279	0.869	0.518
348	48.742	1337	50.703	129	23.250	179	0.961	0.459
413	27.431	472	25.703	41	13.045	63	1.067	0.508
476	16.549	187	7.622	8	3.464	11	2.171	0.454
547	8.539	67	1.378	1	1.813	4	6.197	1.316
609	4.053	23	---	---	1.259	2	---	---
678	2.125	9	---	---	---	---	---	---

Table 29. Printflex Card Data, Trial Z-1-3, Smith Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
20	0.228	15689	0.154	1054	0.082	1954	1.481	1.625
33	0.512	9003	0.641	1135	0.470	2927	0.799	0.733
53	2.937	12336	3.846	1654	3.052	4507	0.764	0.794
86	8.102	10785	11.333	1543	9.463	4430	0.715	0.835
119	14.181	8287	23.077	1381	18.896	3884	0.615	0.819
151	21.402	6387	35.641	1089	29.769	3125	0.600	0.835
187	20.617	3662	35.154	639	29.358	1834	0.586	0.835
215	31.966	3446	66.615	735	53.701	2036	0.480	0.806
259	30.215	1936	85.077	558	59.022	1330	0.355	0.694
305	21.465	889	70.513	299	50.522	736	0.304	0.716
348	21.609	566	83.538	224	60.358	556	0.259	0.723
413	8.703	143	58.282	98	36.858	213	0.149	0.632
476	3.336	36	47.077	52	19.761	75	0.071	0.420
547	0.533	4	6.513	5	4.933	13	0.082	0.757
609	0.370	2	7.205	4	2.619	5	0.051	0.363
678	---	---	2.410	1	1.410	2	---	0.585

Table 30. Printflex Card Data, Trial Z-2-4, Canyon Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
20	0.084	5772	0.051	423	0.339	7797	1.647	6.647
33	0.269	4771	0.333	590	0.528	3096	0.808	1.586
53	1.538	6493	1.667	714	2.110	2958	0.923	1.266
86	5.332	7133	4.923	672	5.827	2584	1.083	1.184
119	10.561	6204	9.538	571	10.551	2055	1.107	1.106
151	17.392	5218	13.769	421	17.811	1772	1.263	1.294
187	17.475	3120	14.513	264	18.441	1092	1.204	1.271
215	30.350	3289	22.923	253	31.693	1139	1.324	1.383
259	33.008	2126	30.949	203	33.008	705	1.067	1.067
305	29.663	1235	25.000	106	29.913	413	1.187	1.197
348	39.574	1042	29.462	79	34.134	298	1.343	1.159
413	26.520	438	14.282	24	17.165	94	1.857	1.202
476	17.149	186	8.154	9	9.173	33	2.103	1.125
547	10.755	81	2.615	2	4.803	12	4.113	1.837
609	6.423	35	---	---	1.661	3	---	---
678	2.214	9	---	---	0.740	1	---	---

Table 31. Printflex Card Data, Trial Z-2-5, Lower Blodgett

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
20	0.252	17473	0.600	4364	0.570	12433	0.420	0.950
33	0.569	10098	0.750	1363	0.777	4344	0.759	1.036
53	2.127	9027	2.150	947	2.901	3872	0.989	1.349
86	6.135	8250	6.025	843	7.760	3281	1.018	1.288
119	11.197	6613	10.750	660	13.314	2471	1.042	1.239
151	18.917	5705	18.600	583	20.521	1945	1.017	1.103
187	18.548	3329	20.325	379	19.256	1086	0.913	0.947
215	31.029	3380	41.875	474	33.504	1147	0.741	0.800
259	34.335	2223	43.700	294	29.736	605	0.786	0.680
305	28.719	1202	37.475	163	26.992	355	0.766	0.720
348	34.421	911	47.650	131	28.248	235	0.722	0.593
413	19.094	317	24.925	43	19.165	100	0.766	0.769
476	12.932	141	15.000	17	8.174	28	0.862	0.545
547	4.491	34	7.625	6	3.364	8	0.589	0.441
609	1.826	10	---	---	2.322	4	---	---
678	0.979	4	---	---	---	---	---	---

Table 32. Printflex Card Data, Trial Z-2-6, Big Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
20	.306		.200		.197		1.53	.98
33	1.116		1.425		1.086		.78	.76
53	3.323		4.725		2.622		.70	.55
86	7.998		11.750		6.764		.68	.57
119	13.641		20.925		12.259		.65	.59
151	18.906		31.975		19.669		.59	.61
187	16.458		28.900		21.267		.56	.74
215	26.598		47.800		39.157		.55	.82
259	26.212	1698	45.925		42.330		.57	.92
305	18.698	783	29.675		37.157		.63	1.25
348	20.119	533	42.900	118	46.732	408	.47	1.08
413	8.668	144	29.575	51	28.662	157	.29	.97
476	3.842	42	8.825	10	14.732	53	.43	1.67
547	1.321	10	2.550	2	4.008	10	.52	1.6

Table 33. Printflex Card Data, Trial B-1-1, Gash Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
0	0.015	1073	0.081	2584	0.045	1752	0.185	0.333
38	1.207	2644	2.707	2954	2.591	3151	0.446	0.466
92	25.990	5867	56.697	6399	58.945	7392	0.458	0.441
186	65.157	3257	195.848	4895	133.191	3699	0.333	0.489
278	63.449	1176	277.646	2573	163.545	1684	0.229	0.388
370	47.066	402	252.657	1079	126.655	601	0.186	0.372
470	13.202	63	128.677	307	55.455	147	0.103	0.238
551	5.086	14	92.960	128	39.218	60	0.055	0.130
675	1.278	2	21.697	17	4.591	4	0.059	0.278
805	---		2.040	1	3.664	2		

Table 34. Printflex Card Data, Trial B-1-2, East Sweeney Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
0	0.035	2127	0.041	1332	0.043	1963	0.854	0.814
38	2.435	5381	2.735	2956	2.630	4013	0.890	0.926
92	34.870	7951	54.388	6077	52.319	8231	0.641	0.666
186	63.195	3191	139.153	3443	148.072	5159	0.454	0.427
278	55.765	1044	161.224	1479	164.659	2127	0.346	0.339
370	36.625	316	111.418	471	134.217	799	0.329	0.273
470	10.375	50	45.724	108	50.819	169	0.227	0.204
551	7.190	20	14.673	20	25.529	49	0.490	0.282
675	1.895	3	---	---	6.413	7		
805	---	---			4.384	3		

Table 35. Printflex Card Data, Trial B-1-3, West Sweeney Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
0	0.025	1580	0.031	954	0.026	840	0.806	0.962
38	1.727	3778	2.711	2905	1.852	2357	0.637	0.933
92	27.444	6195	52.412	5796	36.278	4757	0.524	0.756
186	54.571	2728	138.670	3396	91.757	2664	0.394	0.595
278	64.258	1191	180.619	1640	126.704	1364	0.356	0.507
370	37.116	317	147.928	619	104.417	518	0.251	0.355
470	12.157	58	50.907	119	34.635	96	0.239	0.351
551	6.172	17	14.082	19	15.009	24	0.438	0.411
675	0.636	1	1.299	1	2.200	2	0.490	0.289

Table 36. Printflex Card Data, Trial B-2-4, Sawdust Gulch

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
0	0.015	1041	.010	255	0.014	587	1.500	1.400
38	1.139	2445	0.970	1069	1.050	1611	1.174	1.082
92	11.742	2597	26.340	3003	20.763	3290	0.446	0.788
186	24.845	1217	70.660	1784	50.612	1776	0.352	0.716
278	16.299	296	67.410	631	50.568	658	0.242	0.750
370	7.289	61	41.260	178	28.353	170	0.177	0.687
470	1.067	5	16.180	39	5.971	20	0.066	
551	1.113	3	7.910	11	5.173	10		
675			1.260	1	0.906	1		

Table 37. Printflex Card Data, Trial B-2-5, Upper Blodgett Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
0	0.010	696	0.020	588	0.016	526	0.500	0.800
38	1.150	2537	2.091	2284	1.424	1970	0.550	0.681
92	17.325	3951	36.515	4122	24.288	3461	0.474	0.665
186	31.350	1583	79.737	1993	48.200	1521	0.393	0.604
278	25.210	472	79.747	739	47.008	550	0.316	0.589
370	11.010	95	51.283	219	26.520	143	0.215	0.517
470	2.490	12	13.414	32	11.616	35	0.186	0.866
551	1.080	3	7.263	10	5.176	9		
675	0.630	1	2.556	2	1.008	1		
805			2.040	1	1.616	1		

Table 38. Printflex Card Data, Trial B-2-6, South Bear Creek

Drop Size (μm)	Under Tree		In Open		Cross		Total Mass Ratio	
	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Mass/ Card (mg)	Total Stains	Under/ Open	Cross/ Open
0	0.016	857	0.020	705	0.017	594	0.800	0.850
38	1.644	3462	2.720	3007	1.864	2431	0.604	0.685
92	33.764	7353	56.260	6414	42.797	5758	0.600	0.761
186	73.099	3525	148.260	3743	108.593	3235	0.493	0.732
278	59.398	1062	168.150	1574	113.797	1257	0.353	0.677
370	28.764	237	114.750	495	85.653	436	0.251	0.746
470	8.471	39	29.050	70	22.508	64	0.292	0.775
551	4.895	13	17.970	25	17.669	29		
675	1.984	3	1.260	1	5.356	5		

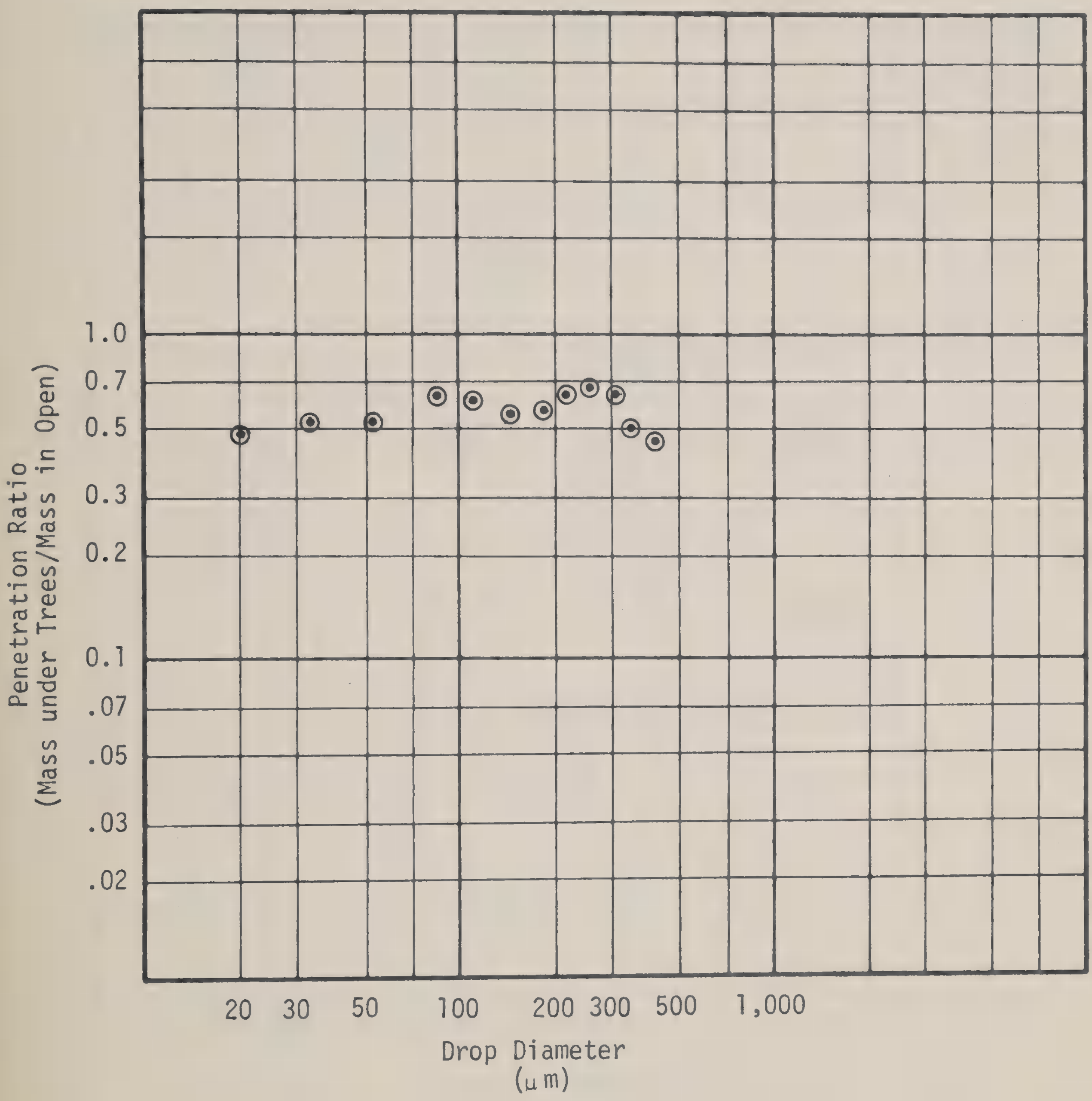
ZECTRAN TRIALS

Z-1-1 Through Z-2-6

Canopy Penetration Plots

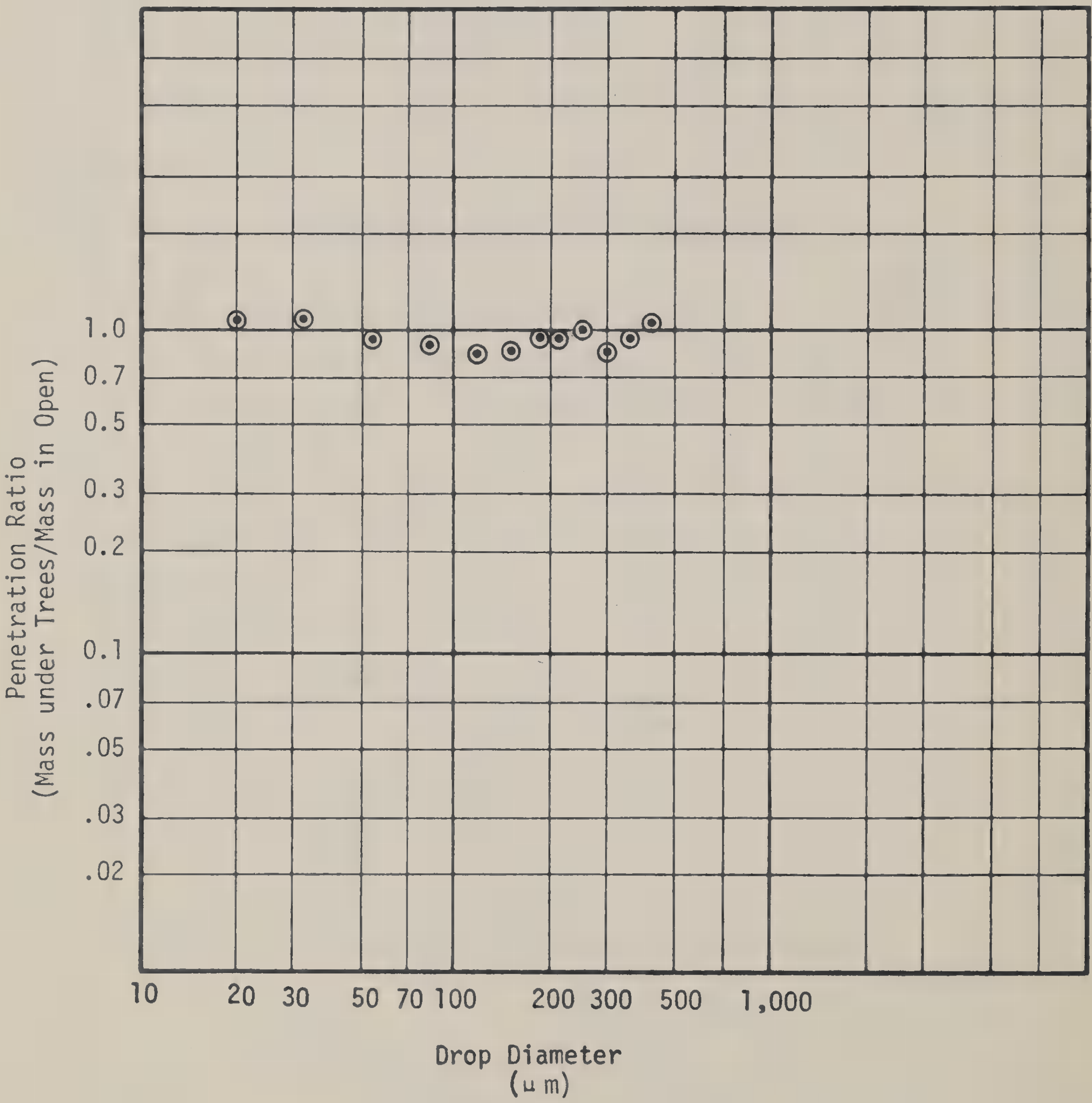
Tree-Card Data to Open-Area Data

Figures 46 Through 51



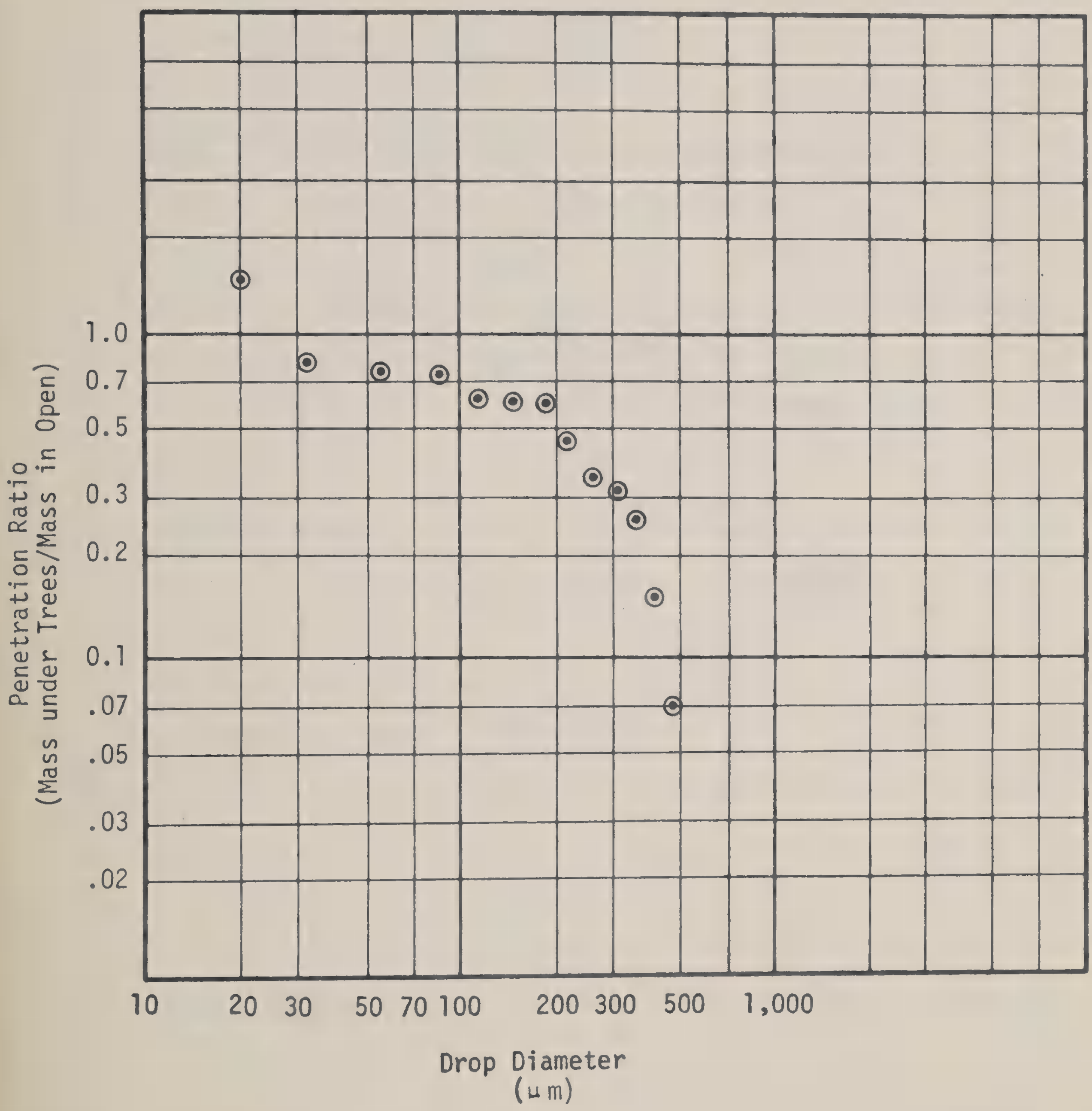
Tree Data to Open-Area Data

Figure 46. Trial Z-1-1, Mill Creek



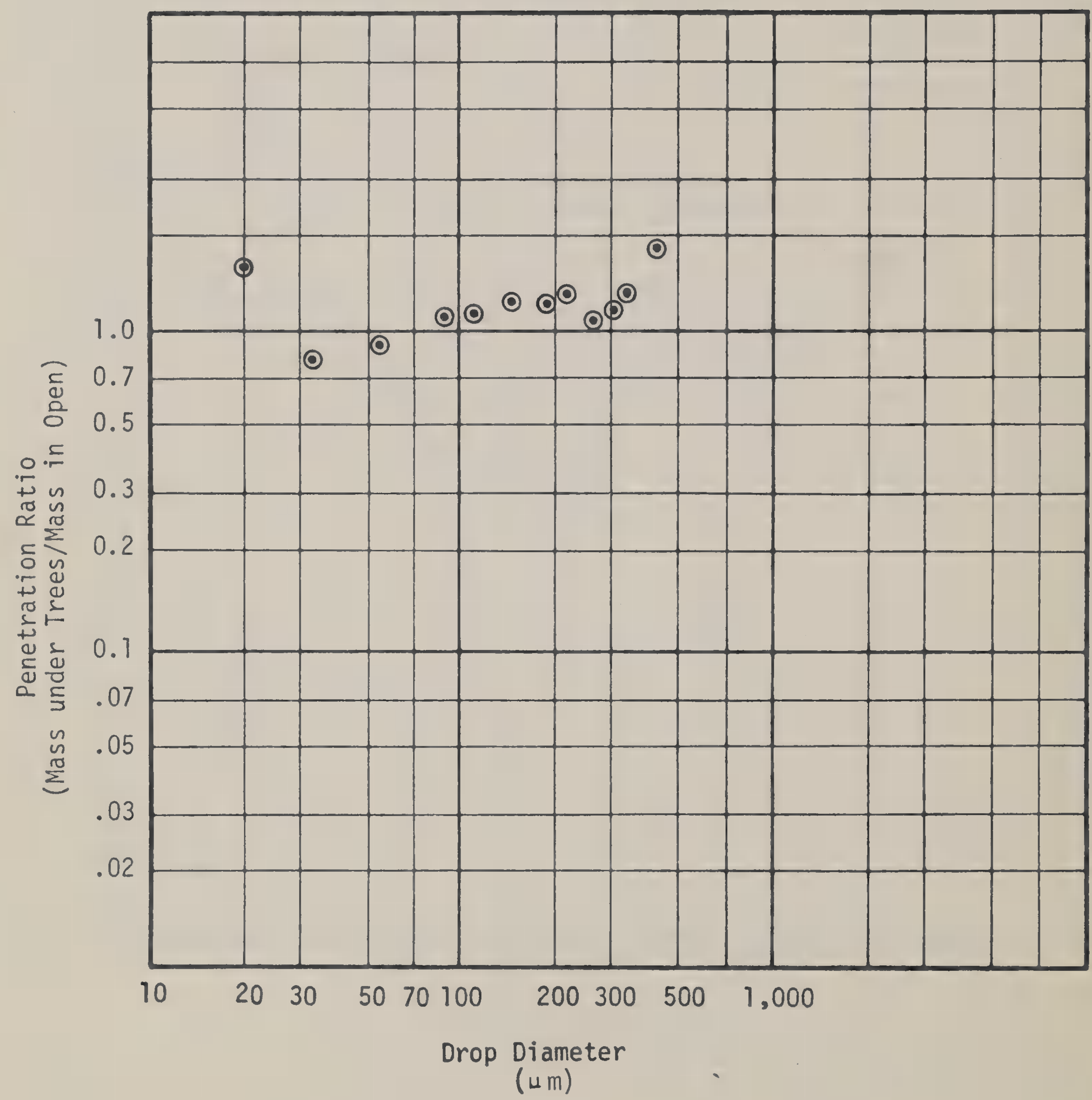
Tree Data to Open-Area Data

Figure 47. Trial Z-1-2, North Bear Creek



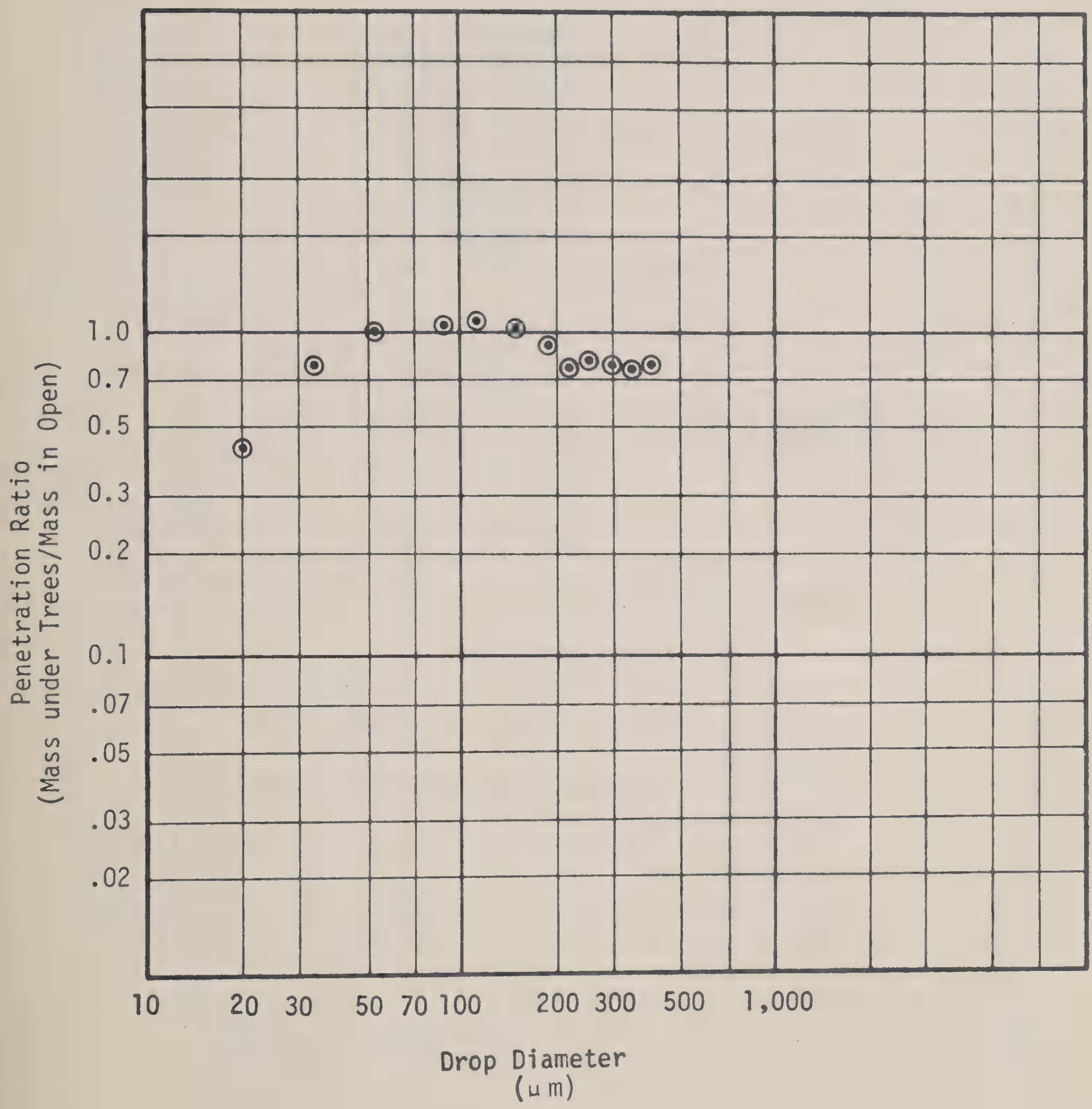
Tree Data to Open-Area Data

Figure 48. Trial Z-1-3, Smith Creek



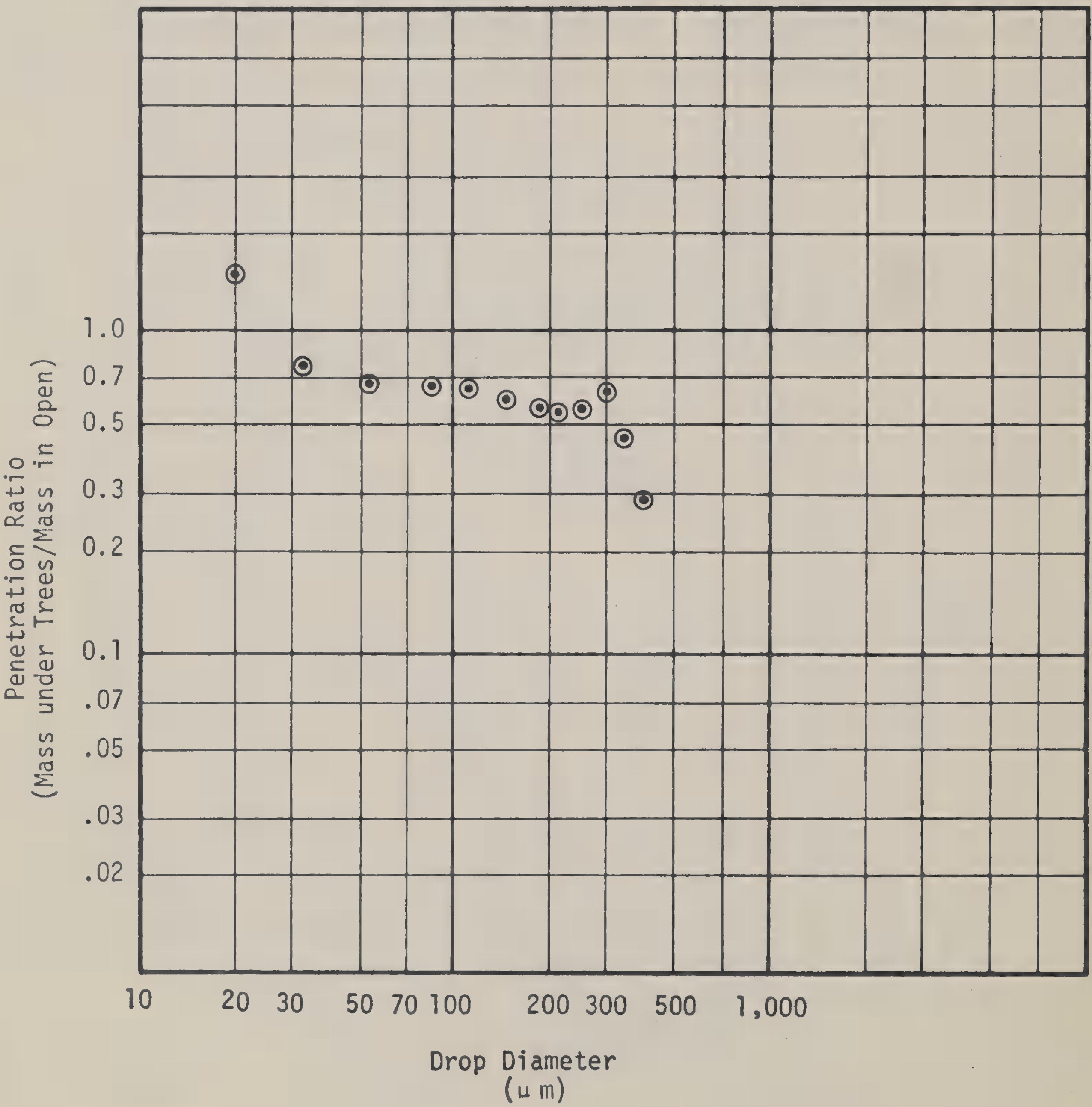
Tree Data to Open-Area Data

Figure 49. Trial Z-2-4, Canyon Creek



Tree Data to Open-Area Data

Figure 50. Trial Z-2-5, Lower Blodgett Creek



Tree Data to Open-Area Data

Figure 51. Trial Z-2-6, Big Creek

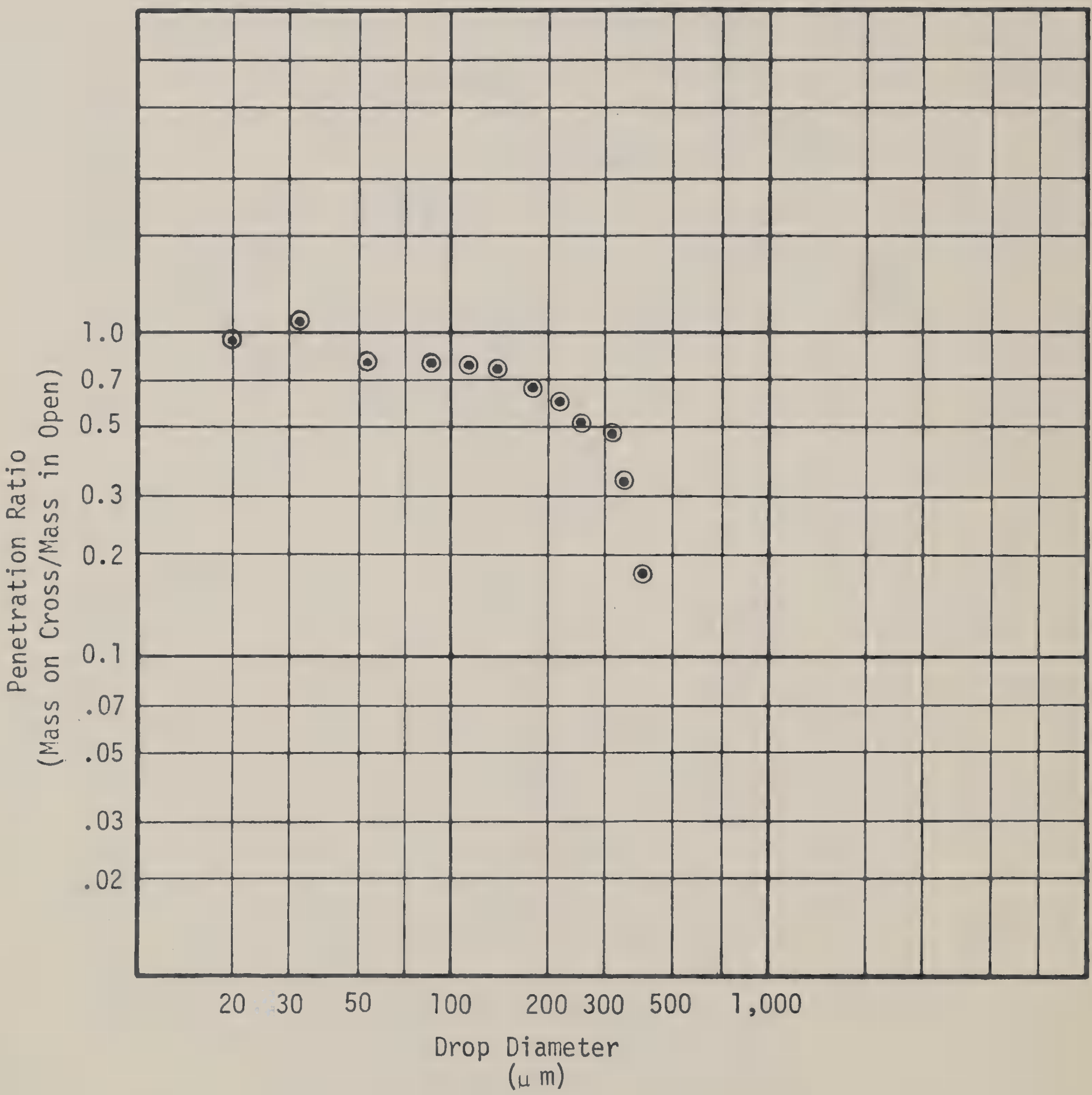
ZECTRAN TRIALS

Z-1-1 Through Z-2-6

Canopy Penetration Plots

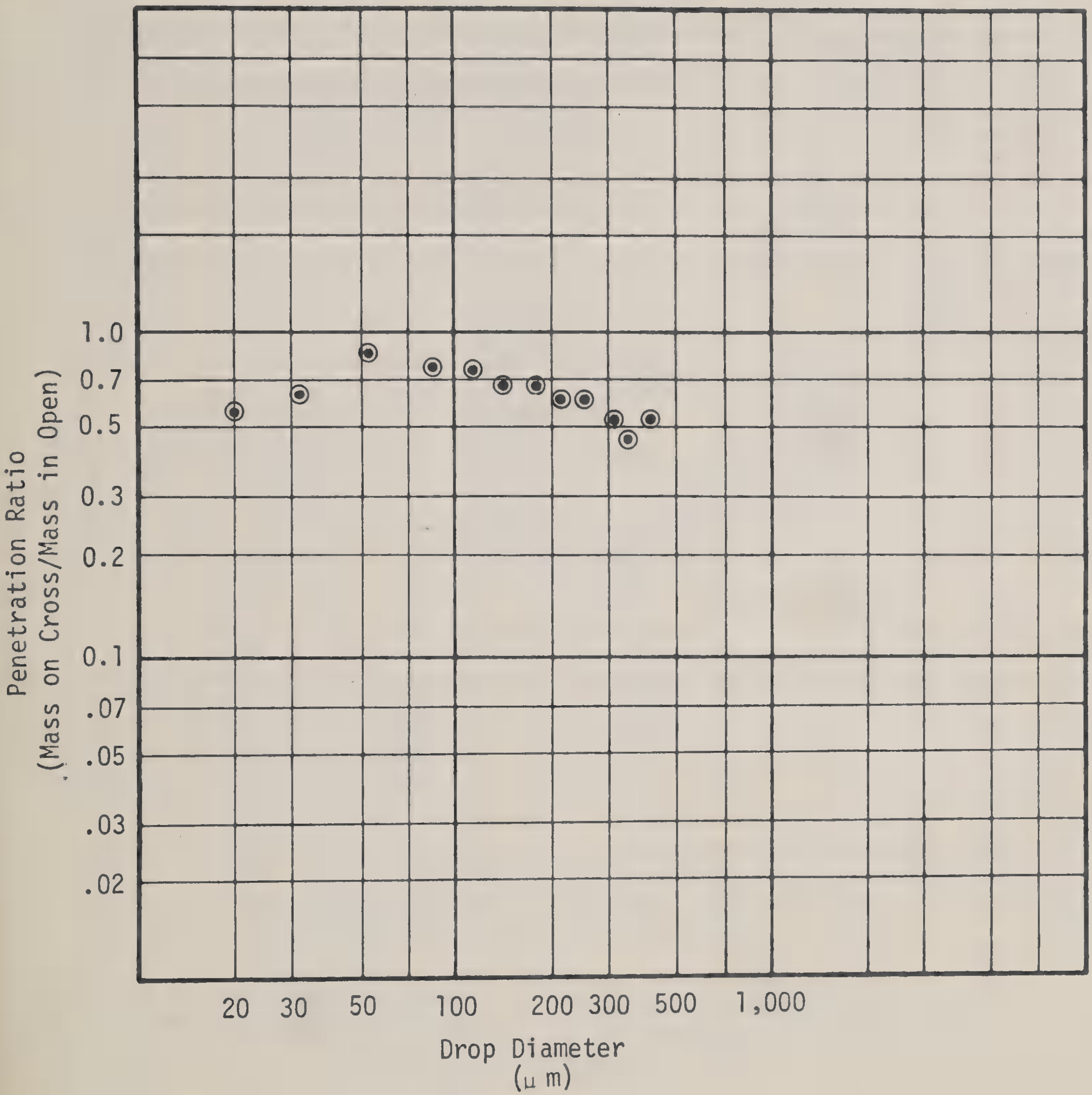
Cross-Card Data to Open-Area Data

Figures 52 Through 57



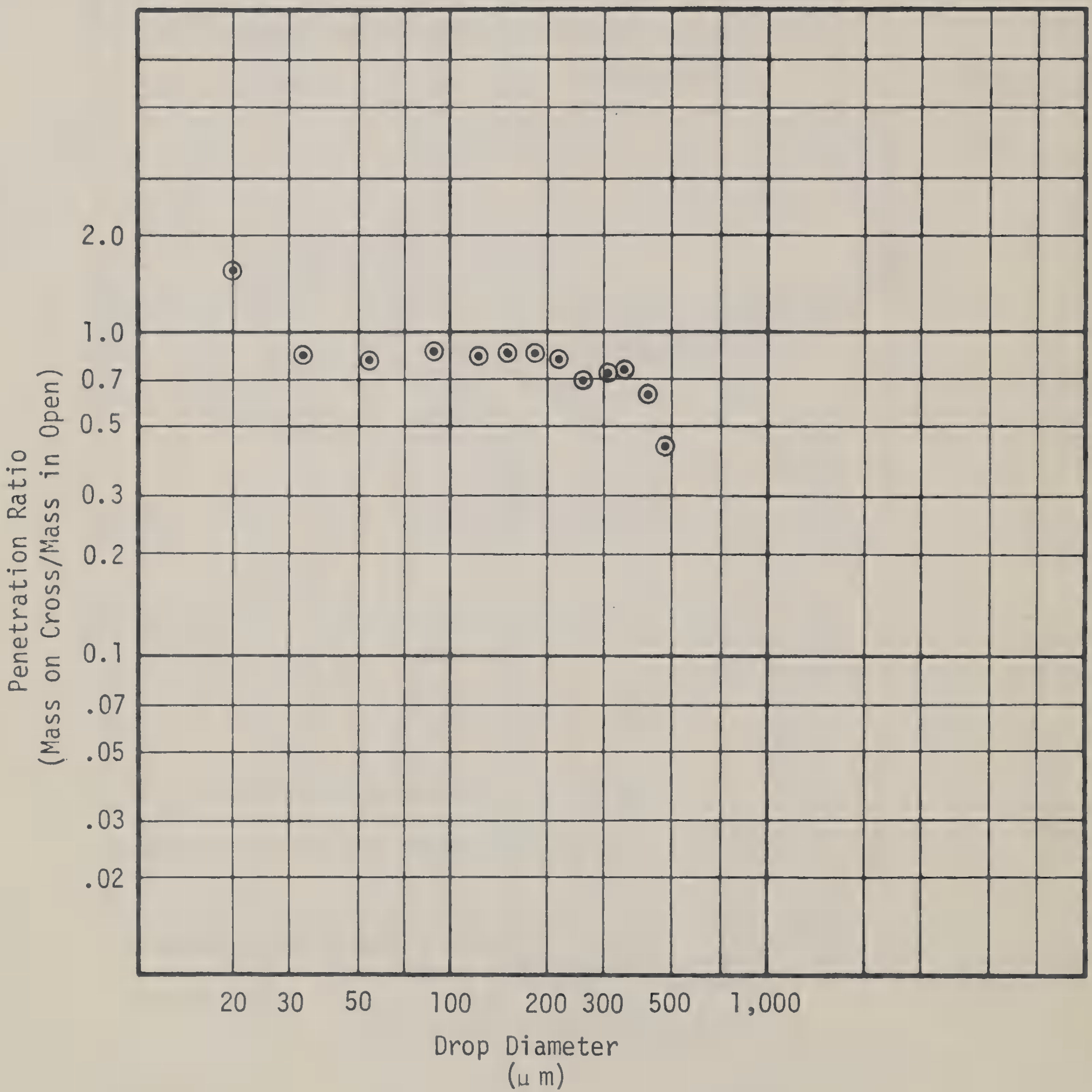
Cross Data to Open-Area Data

Figure 52. Trial Z-1-1, Mill Creek



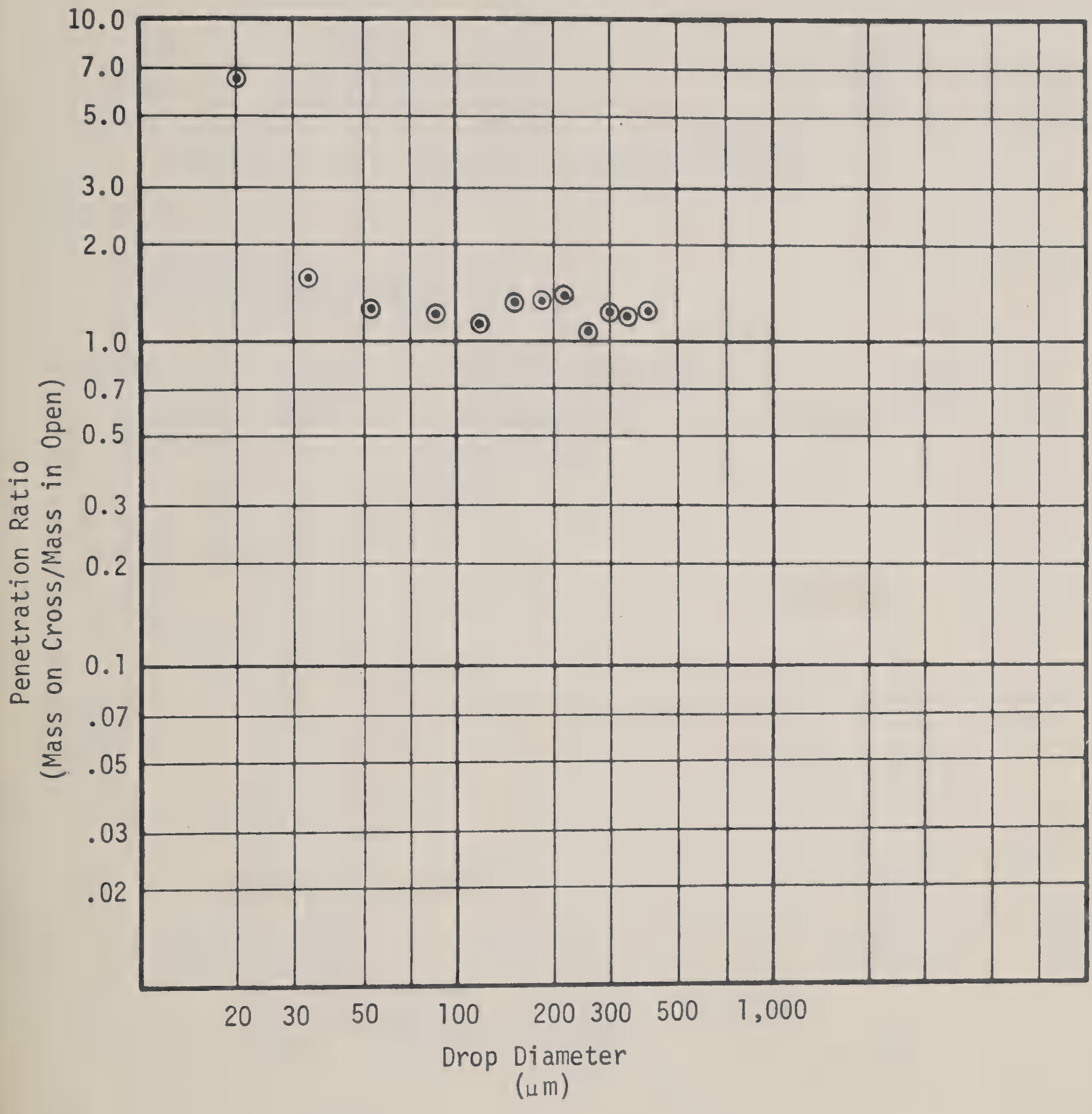
Cross Data to Open-Area Data

Figure 53. Trial Z-1-2, North Bear Creek



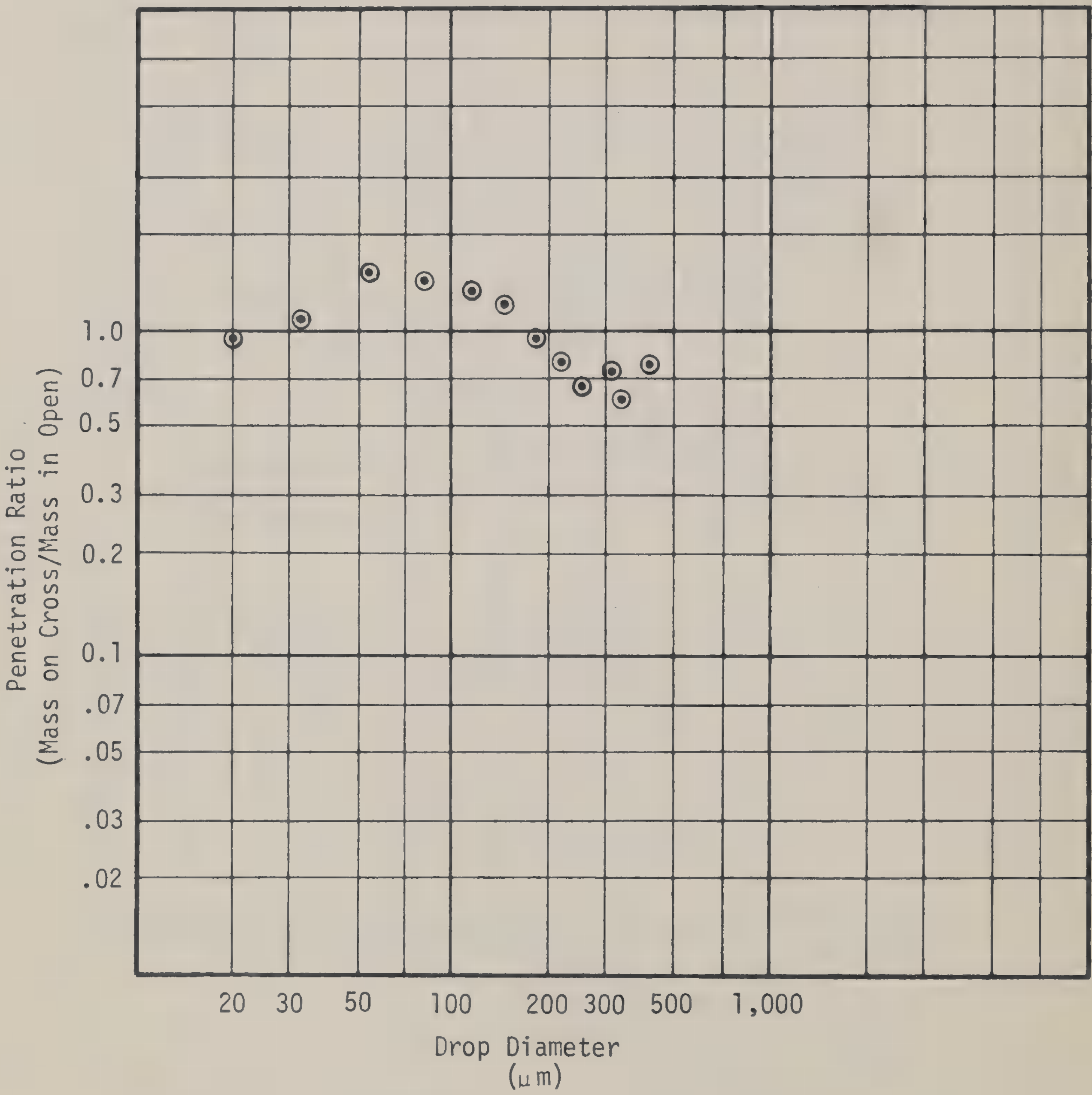
Cross Data to Open-Area Data

Figure 54. Trial Z-1-3, Smith Creek



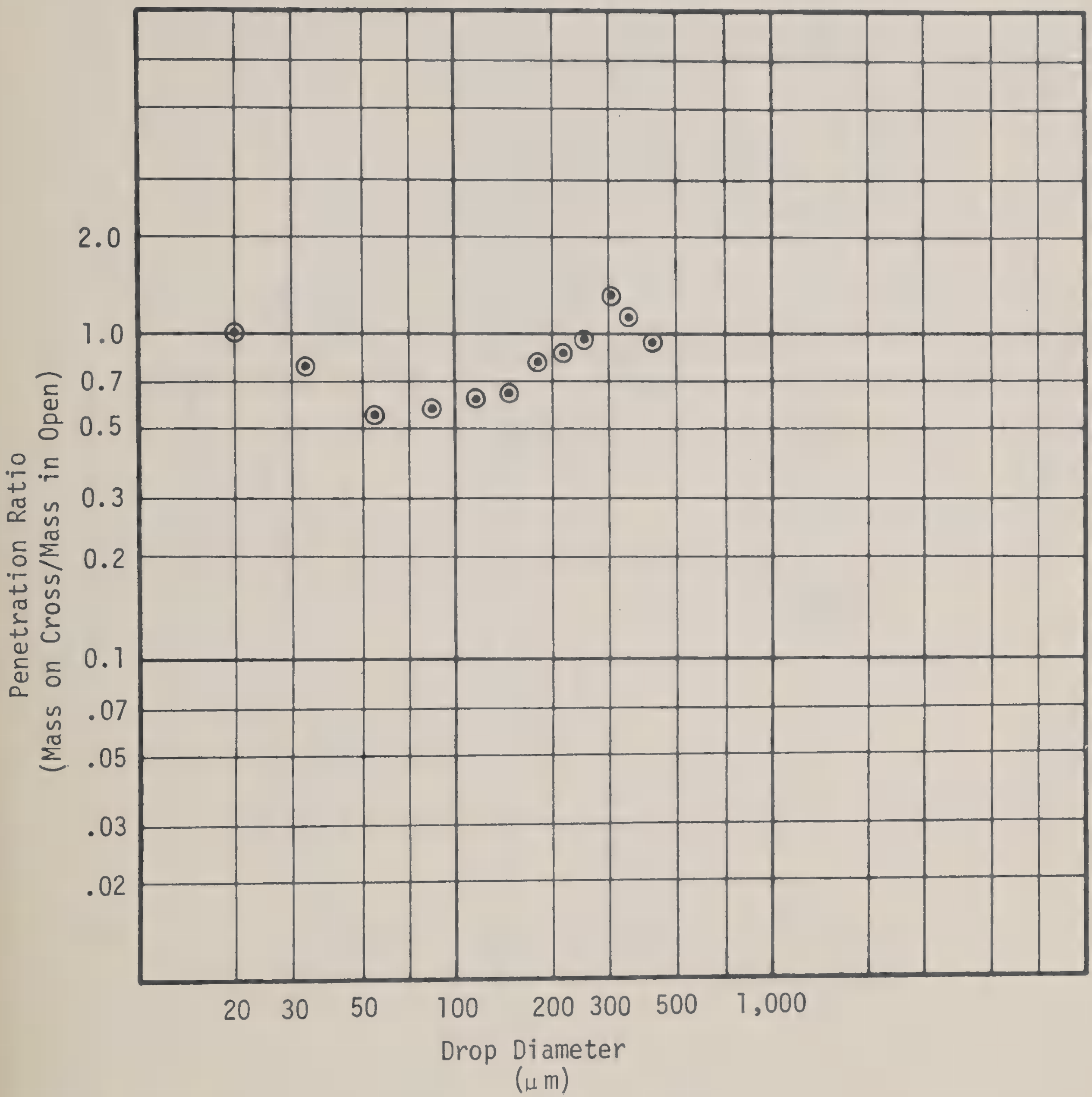
Cross Data to Open-Area Data

Figure 55. Trial Z-2-4, Canyon Creek



Cross Data to Open-Area Data

Figure 56. Trial Z-2-5, Lower Blodgett Creek



Cross Data to Open-Area Data

Figure 57. **Trial Z-2-6, Big Creek**

ZECTRAN TRIALS

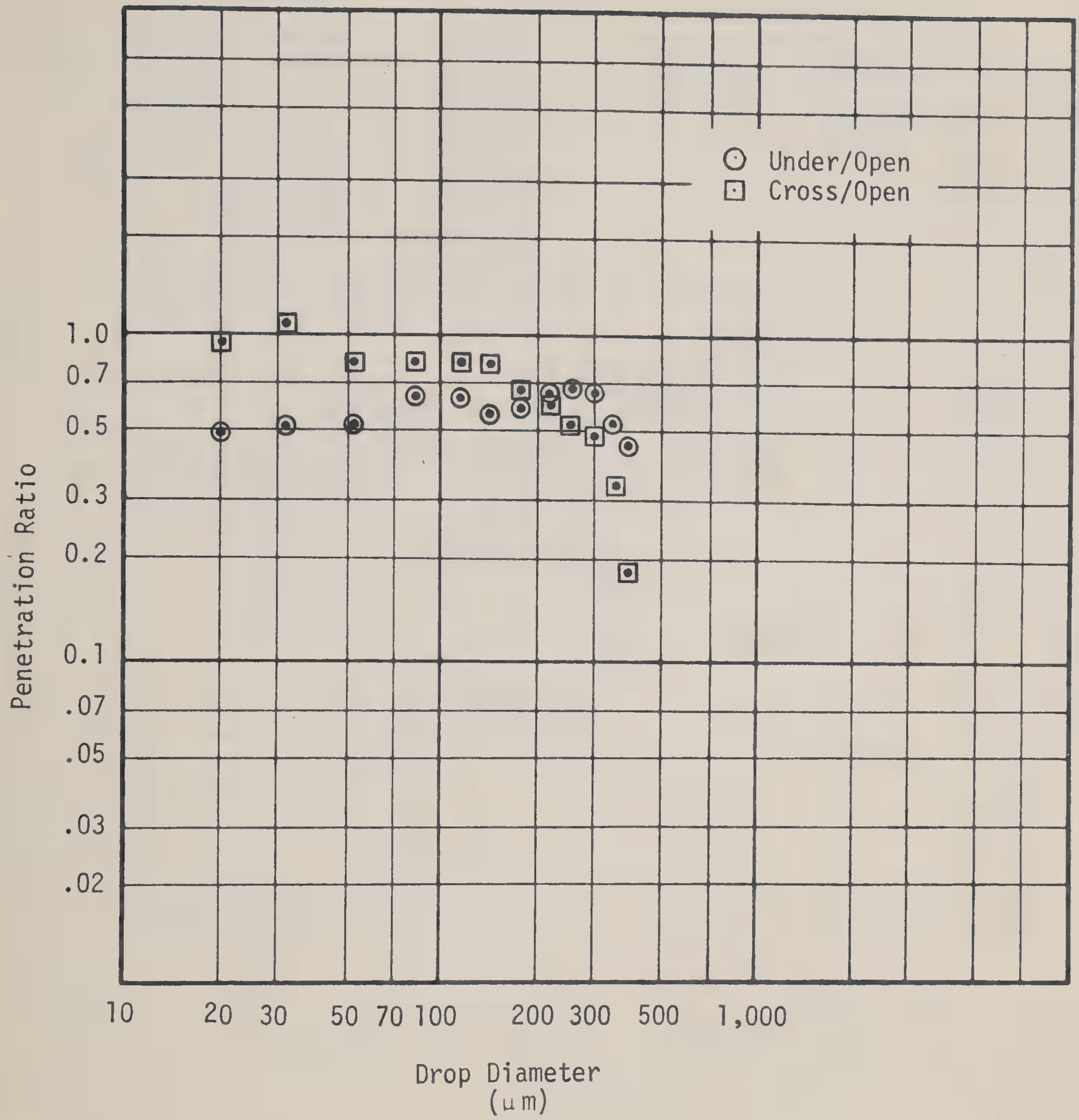
Z-1-1 Through Z-2-6

Canopy Penetration Ratio

Comparison of Tree Data and Cross Data

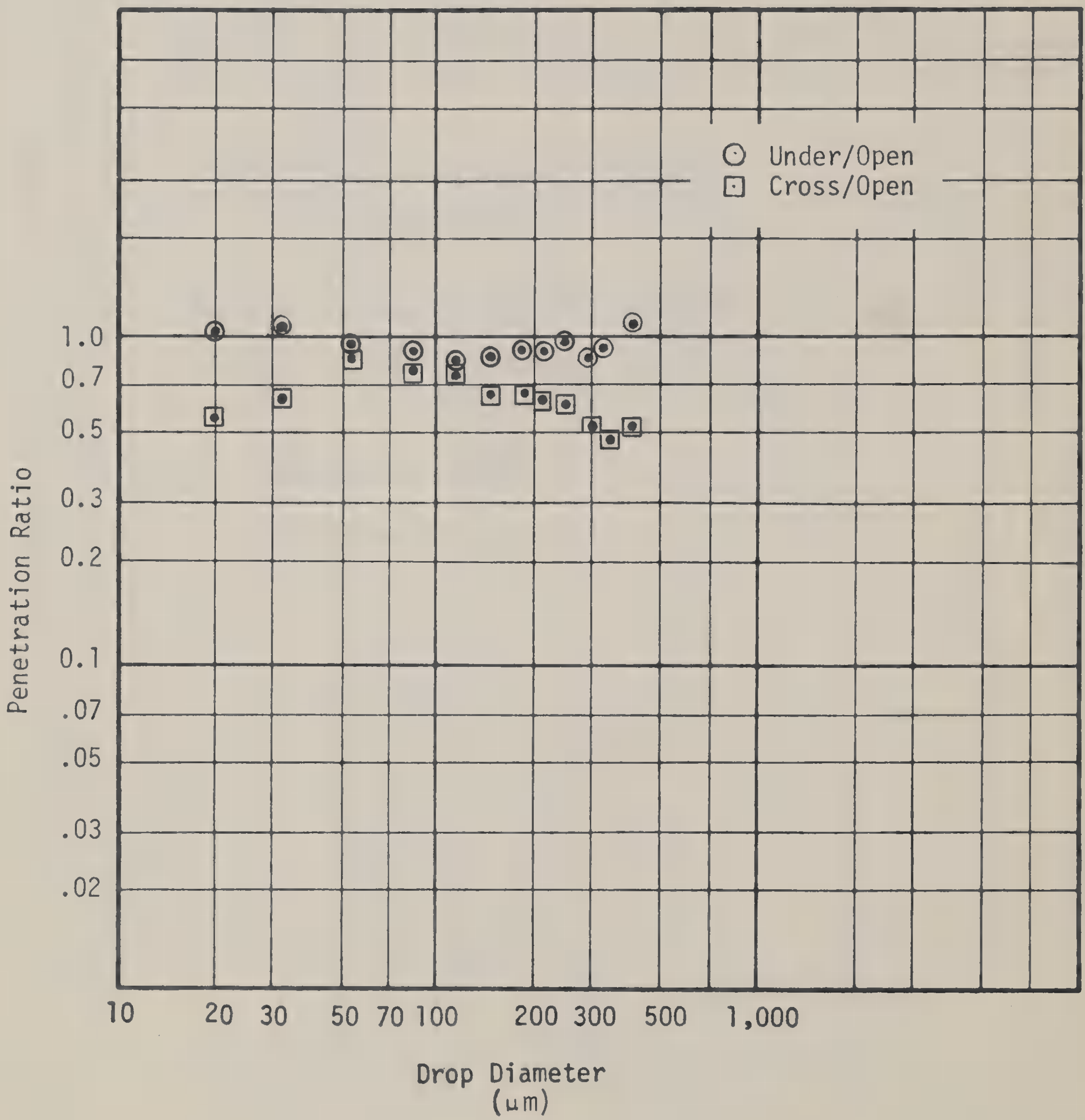
to Open-Area Data

Figures 58 Through 63



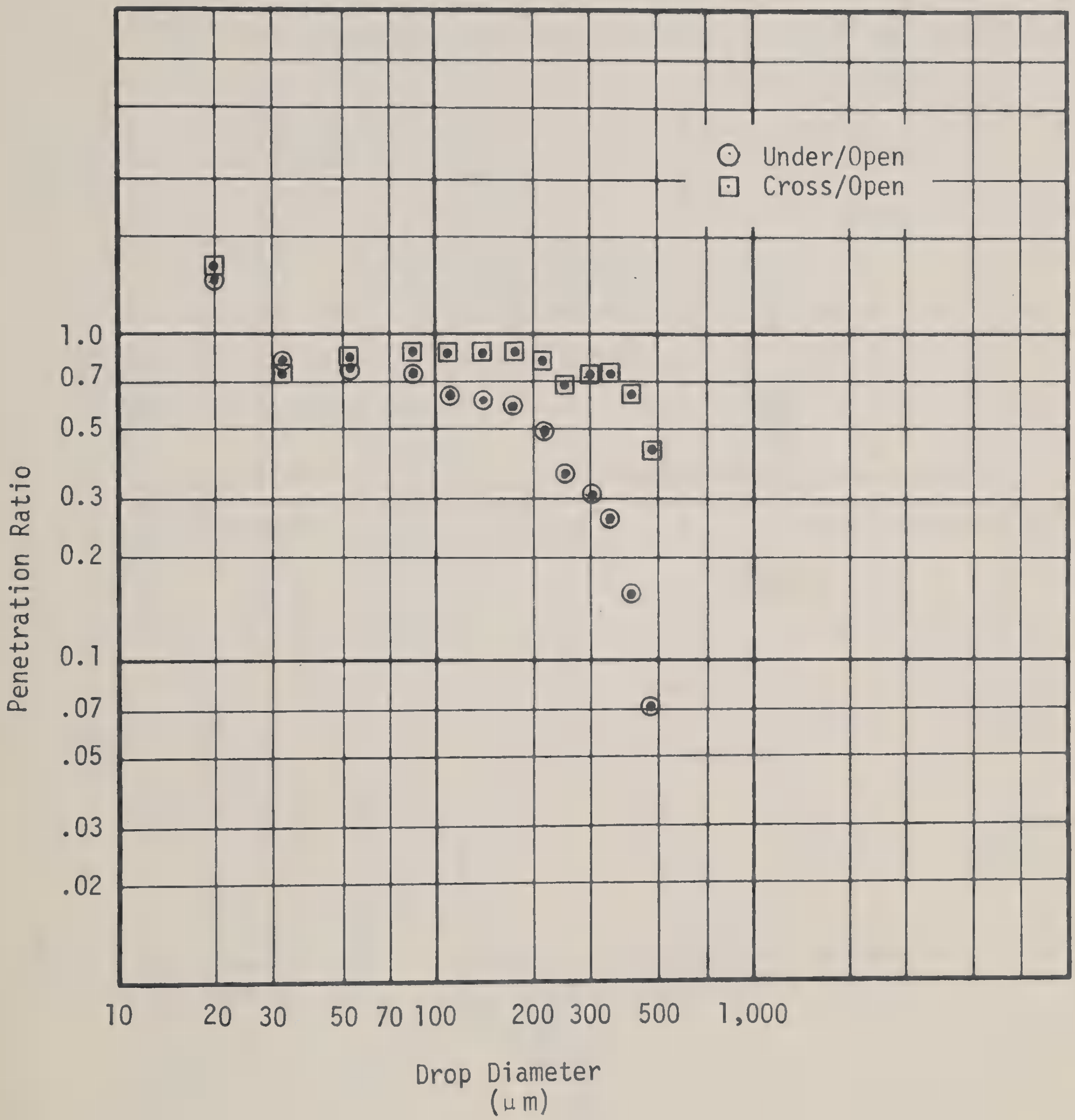
Comparison of Tree Data and Cross Data to Open-Area Data

Figure 58. **Trial Z-1-1, Mill Creek**



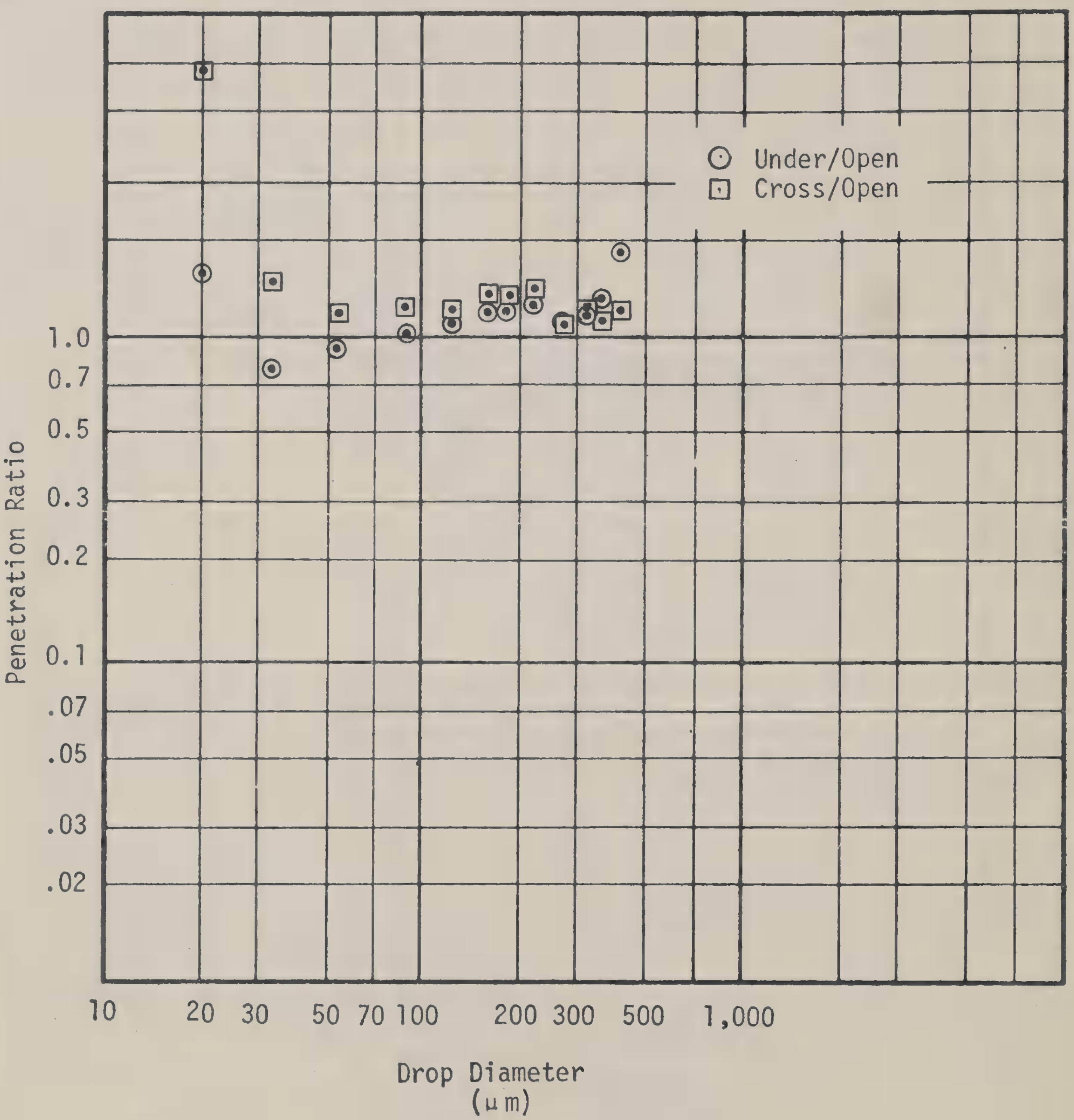
Comparison of Tree Data and Cross Data to Open-Area Data

Figure 59. Trial Z-1-2, North Bear Creek



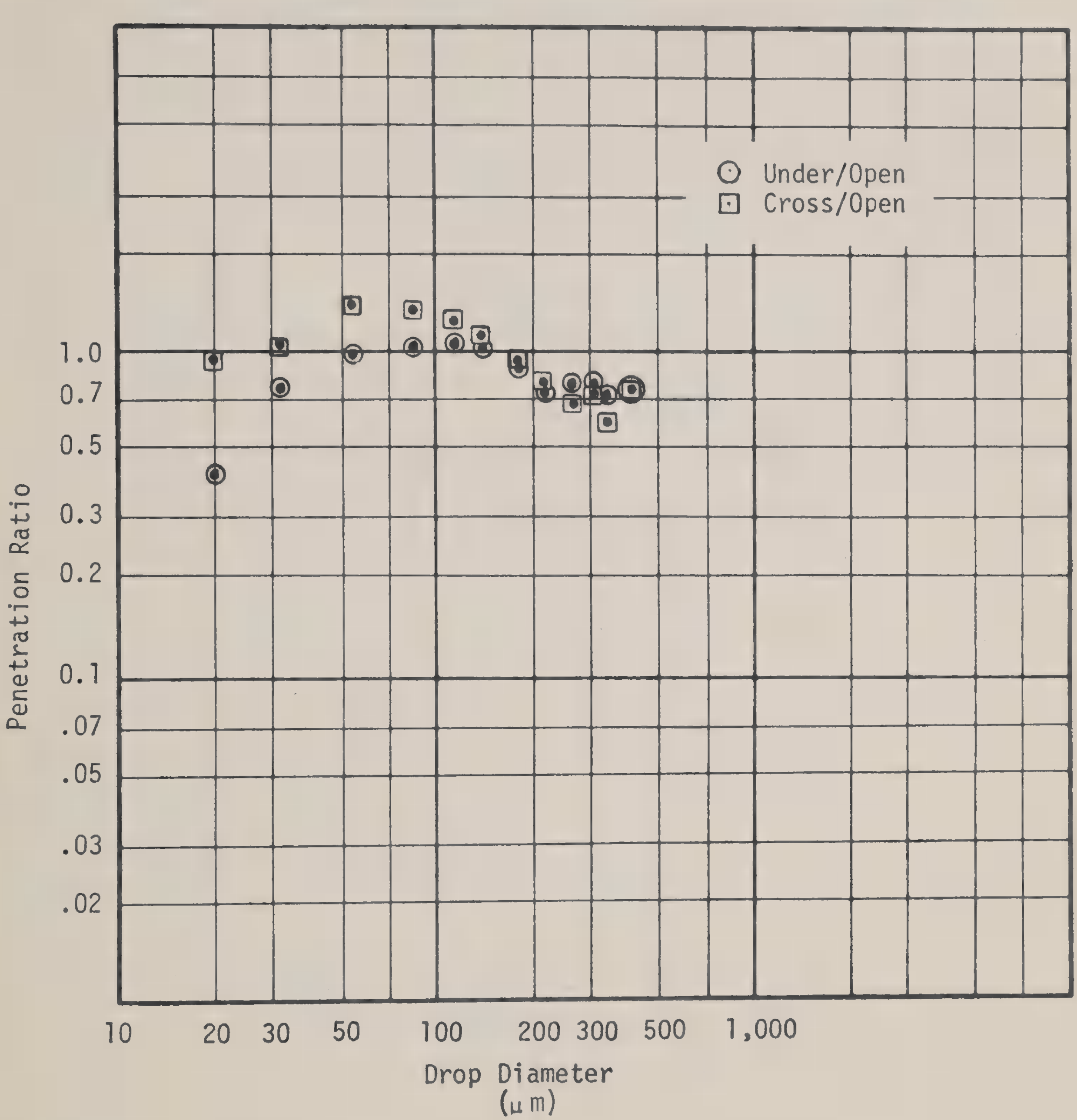
Comparison of Tree Data and Cross Data to Open-Area Data

Figure 60. Trial Z-1-3, Smith Creek



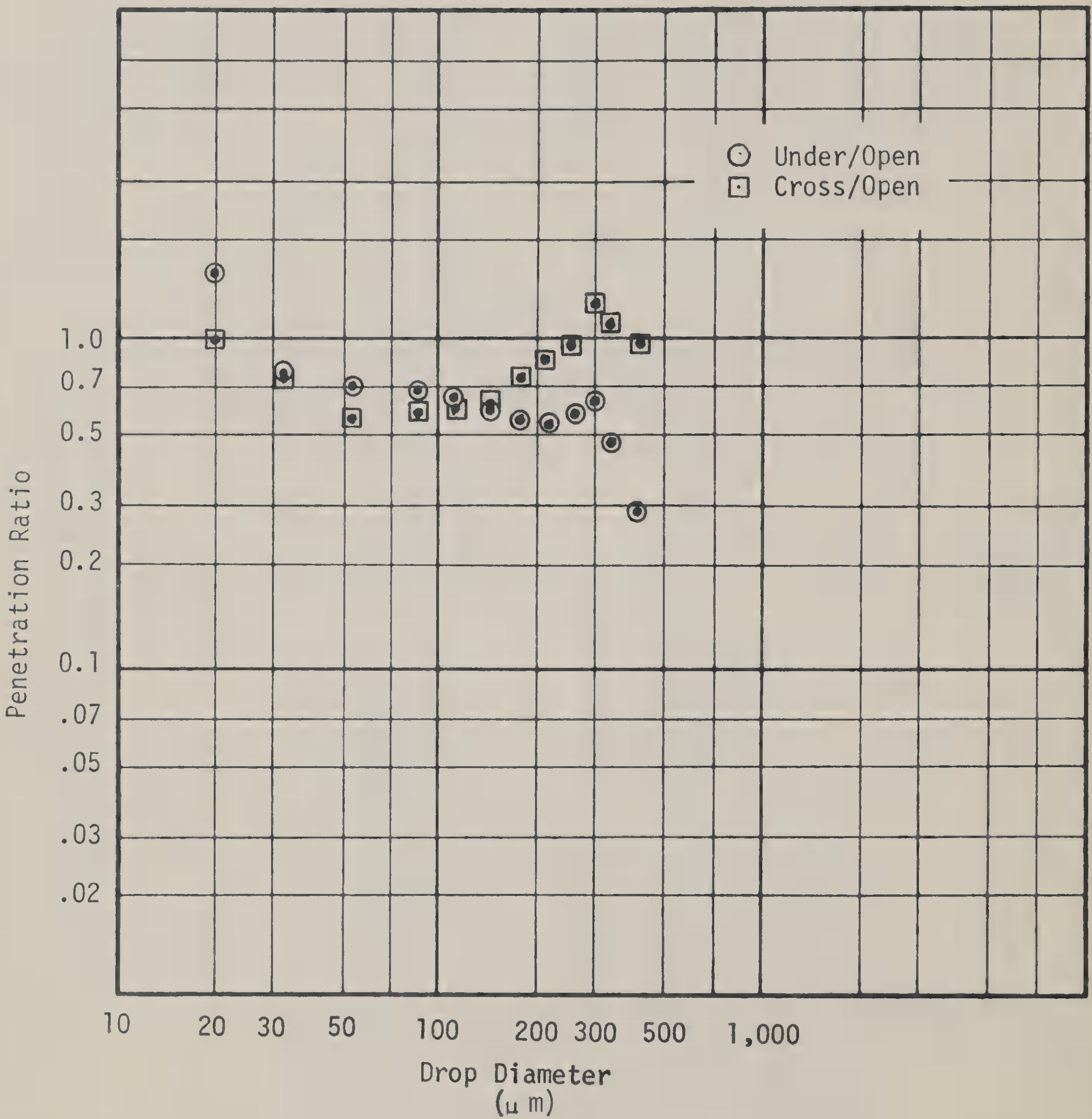
Comparison of Tree Data and Cross Data to Open-Area Data

Figure 61. Trial Z-2-4, Canyon Creek



Comparison of Tree Data and Cross Data to Open-Area Data

Figure 62. Trial Z-2-5, Lower Blodgett Creek



Comparison of Tree Data and Cross Data to Open-Area Data

Figure 63. Trial Z-2-6, Big Creek

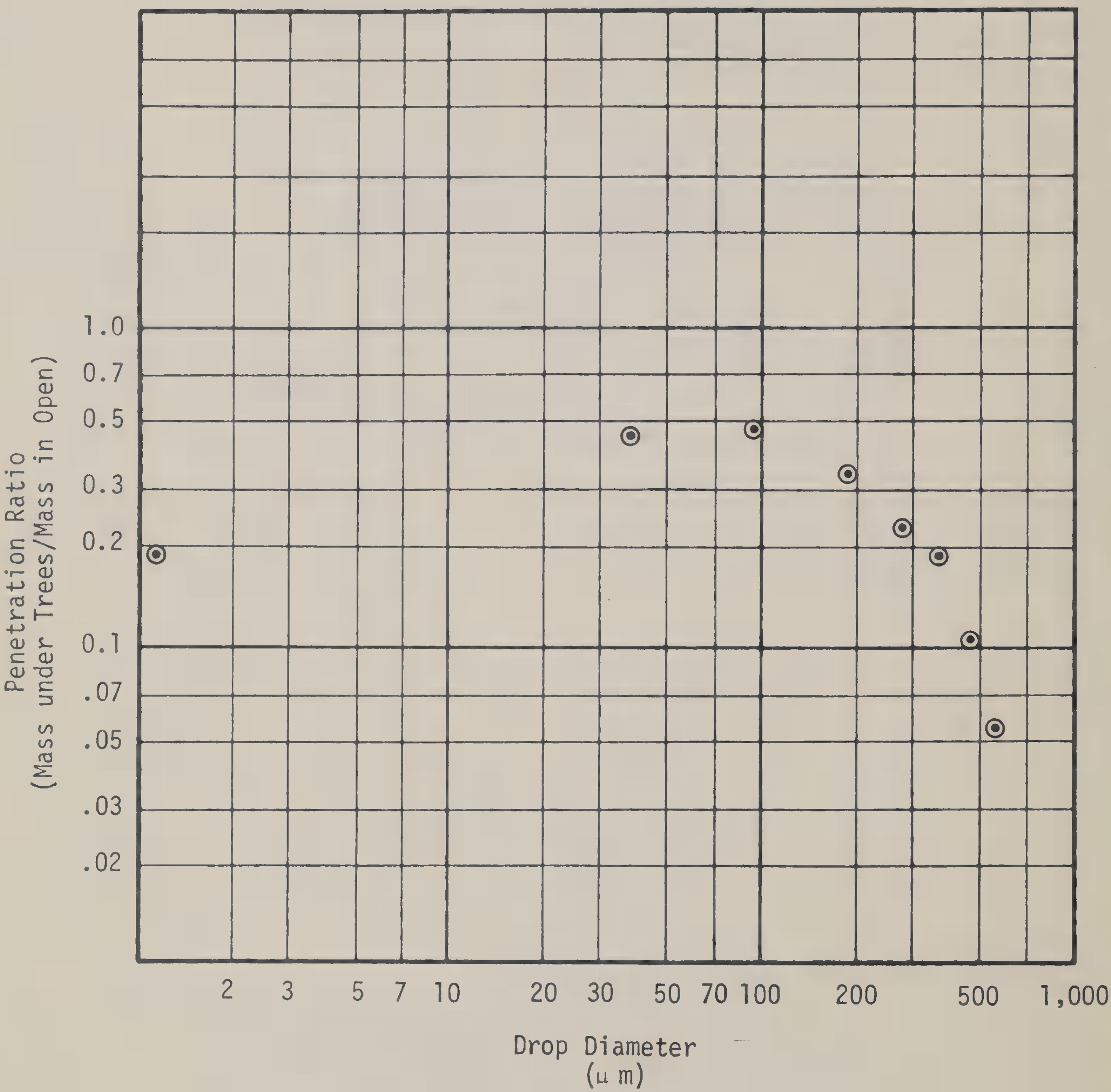
BACILLUS THURINGIENSIS TRIALS

B-1-1 Through B-2-6

Canopy Penetration Plots

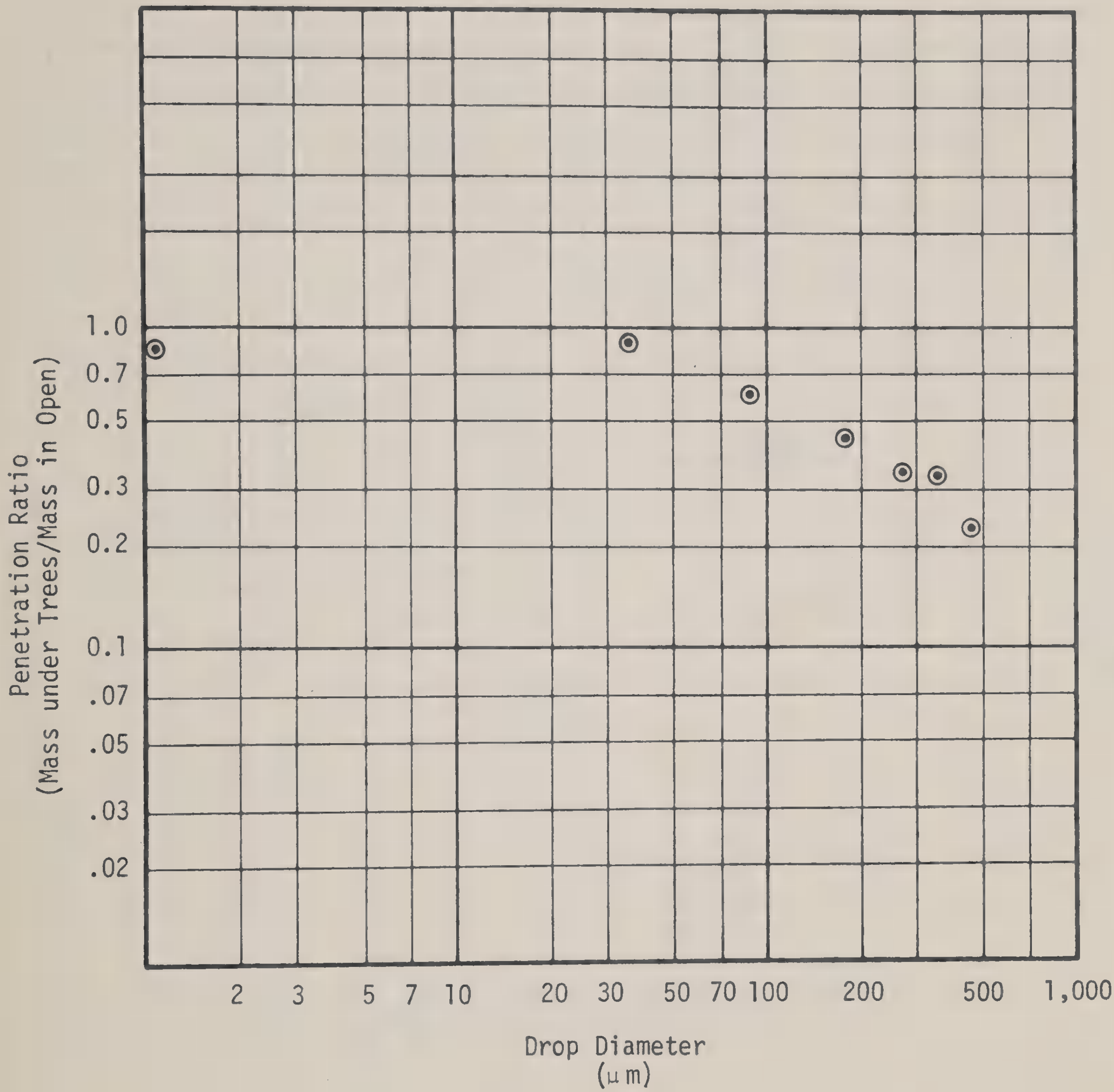
Tree-Card Data to Open-Area Data

Figures 64 Through 69



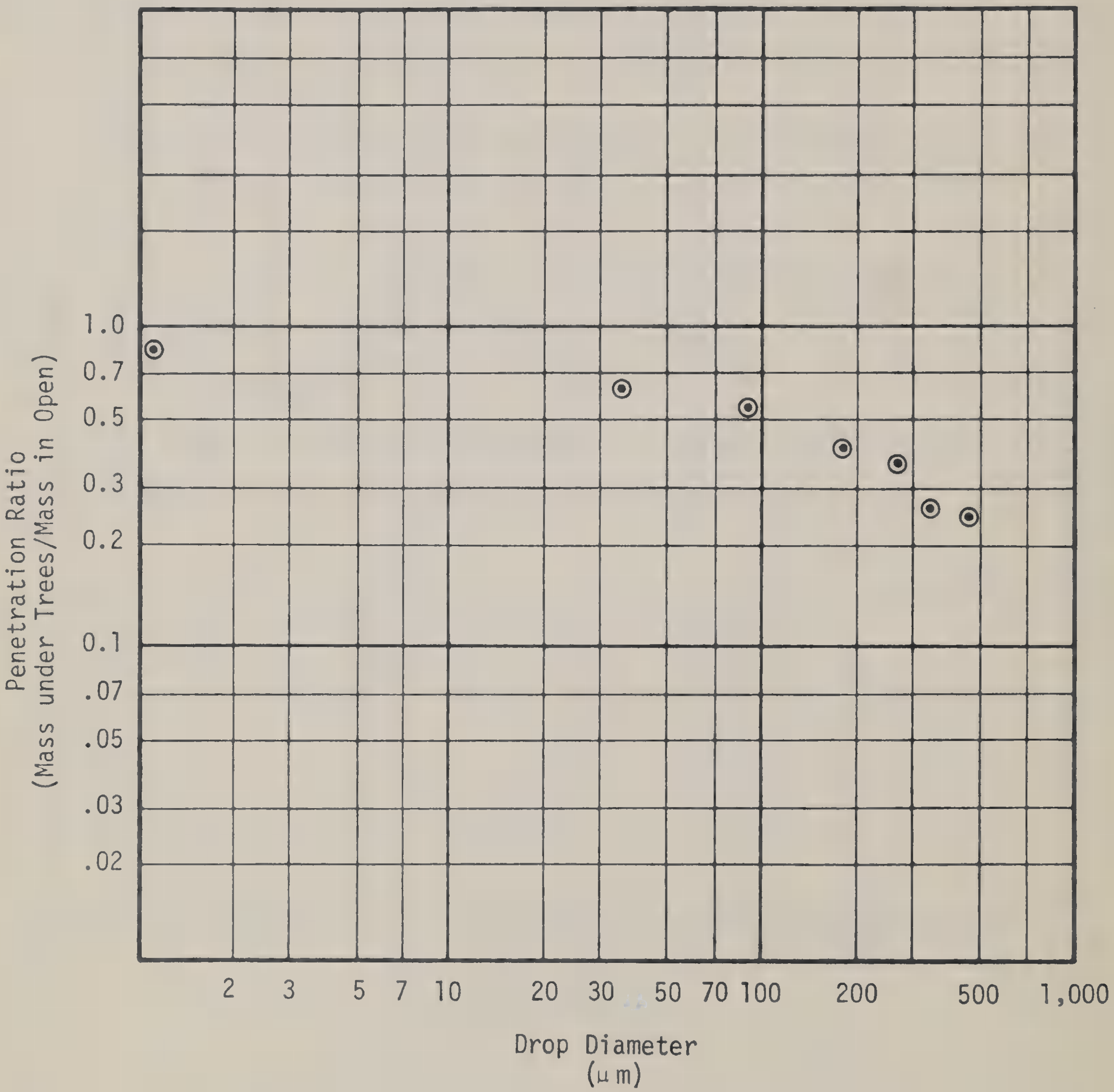
Tree Data to Open-Area Data

Figure 64. Trial B-1-1, Gash Creek



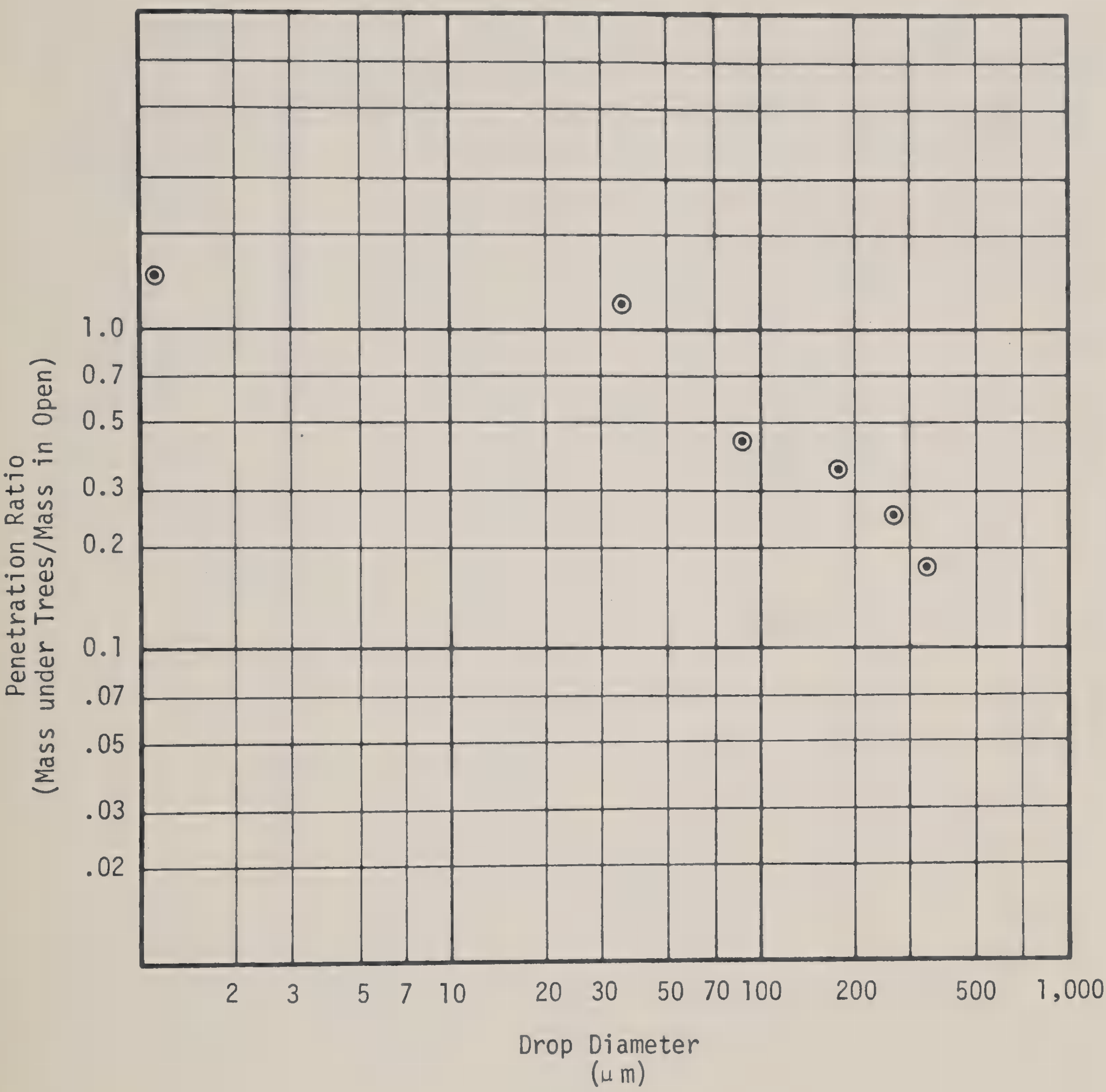
Tree Data to Open-Area Data

Figure 65. Trial B-1-2, East Sweeney Creek



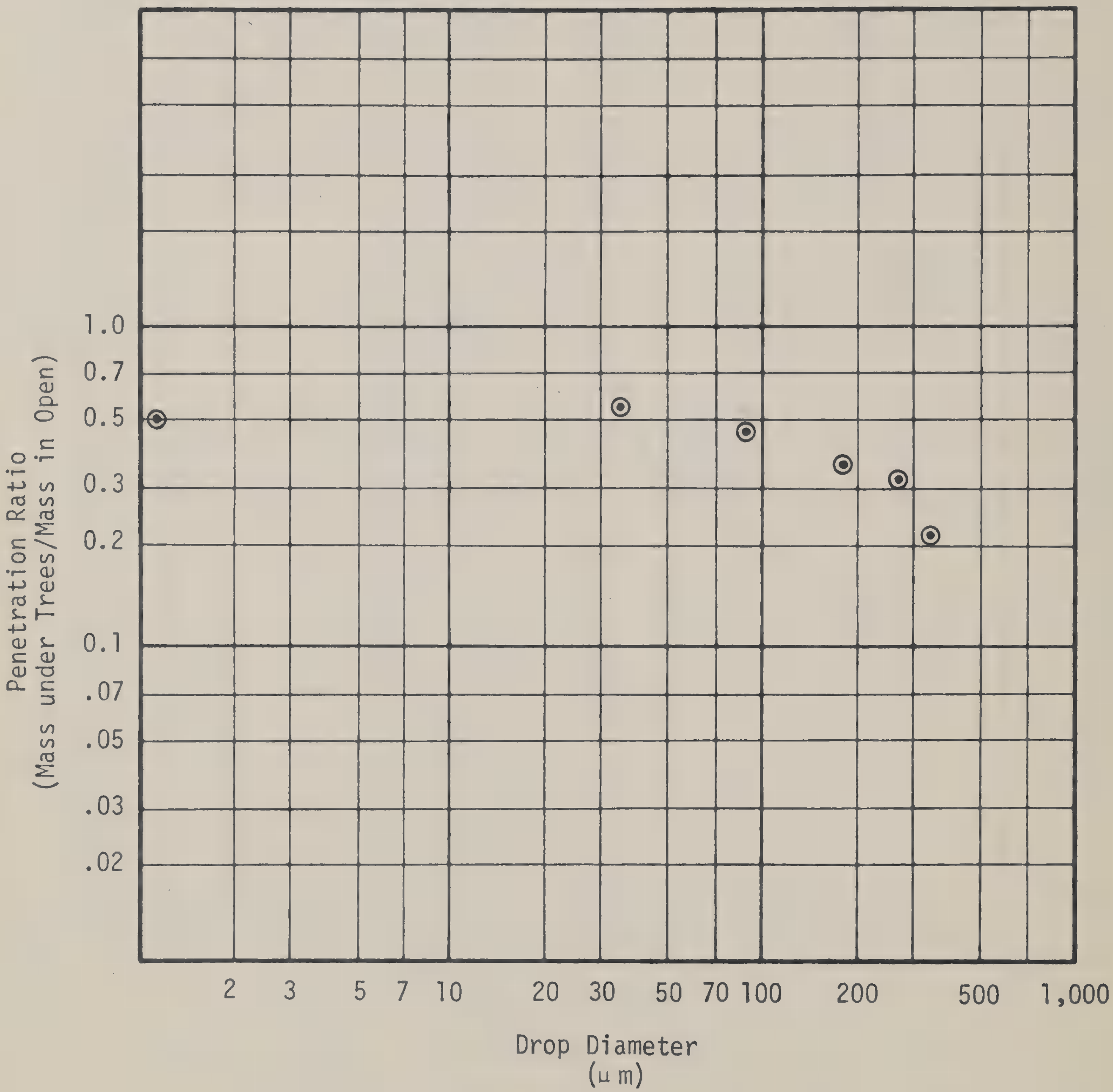
Tree Data to Open-Area Data

Figure 66. Trial B-1-3, West Sweeney Creek



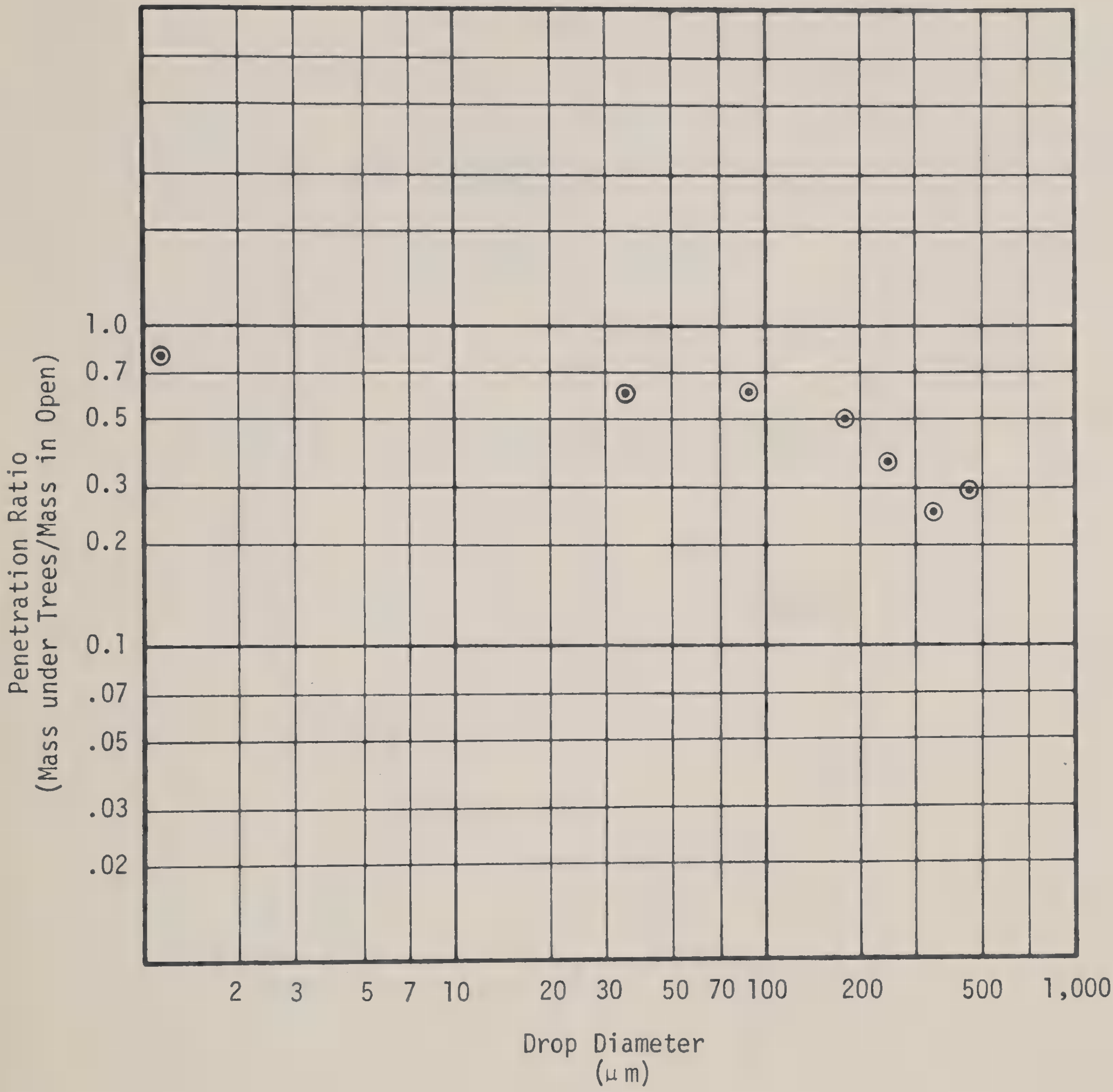
Tree Data to Open-Area Data

Figure 67. Trial B-2-4, Sawdust Gulch



Tree Data to Open-Area Data

Figure 68. Trial B-2-5, Upper Blodgett Creek



Tree Data to Open-Area Data

Figure 69. Trial B-2-6, South Bear Creek

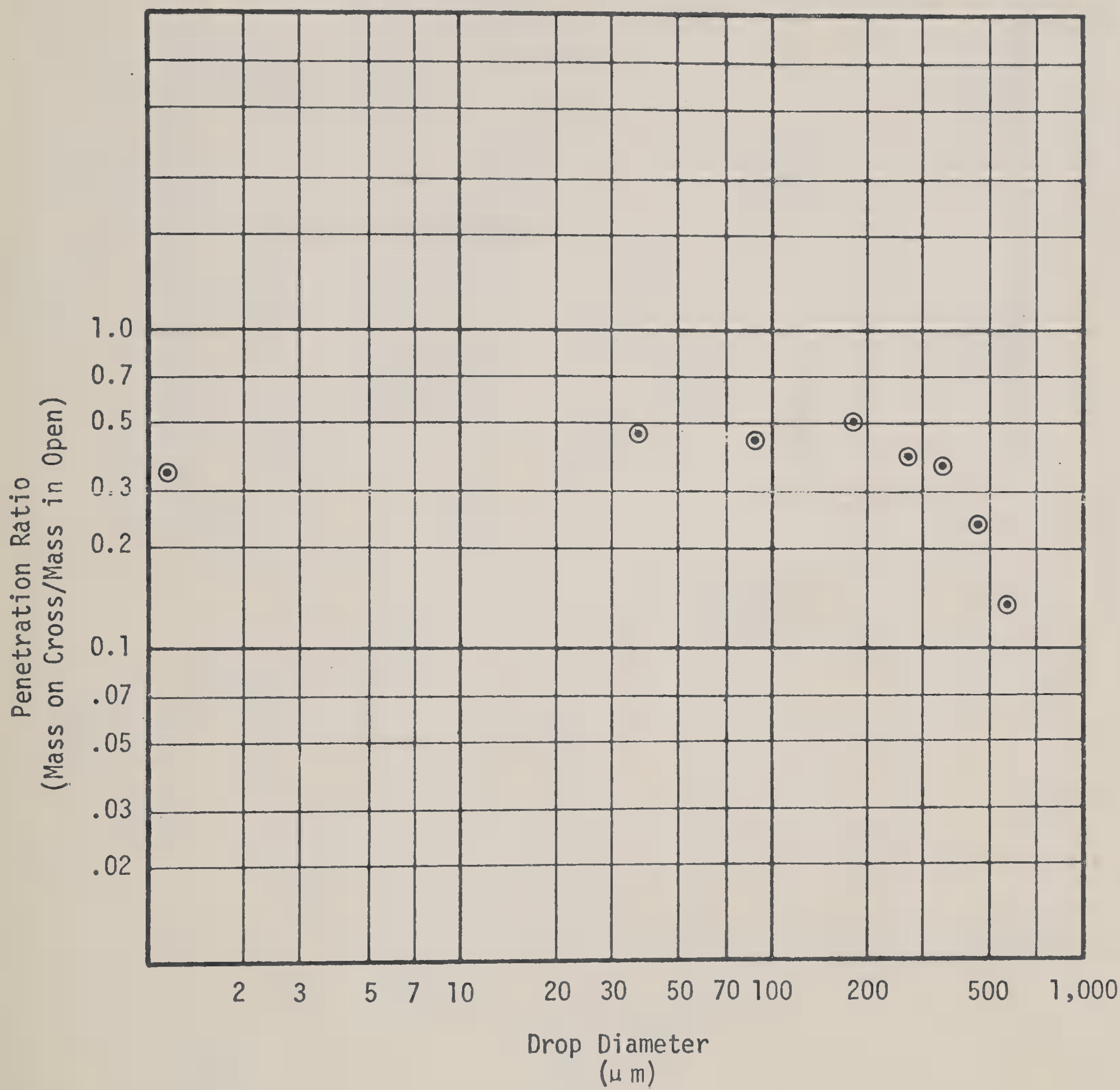
BACILLUS THURINGIENSIS TRIALS

B-1-1 Through B-2-6

Canopy Penetration Plots

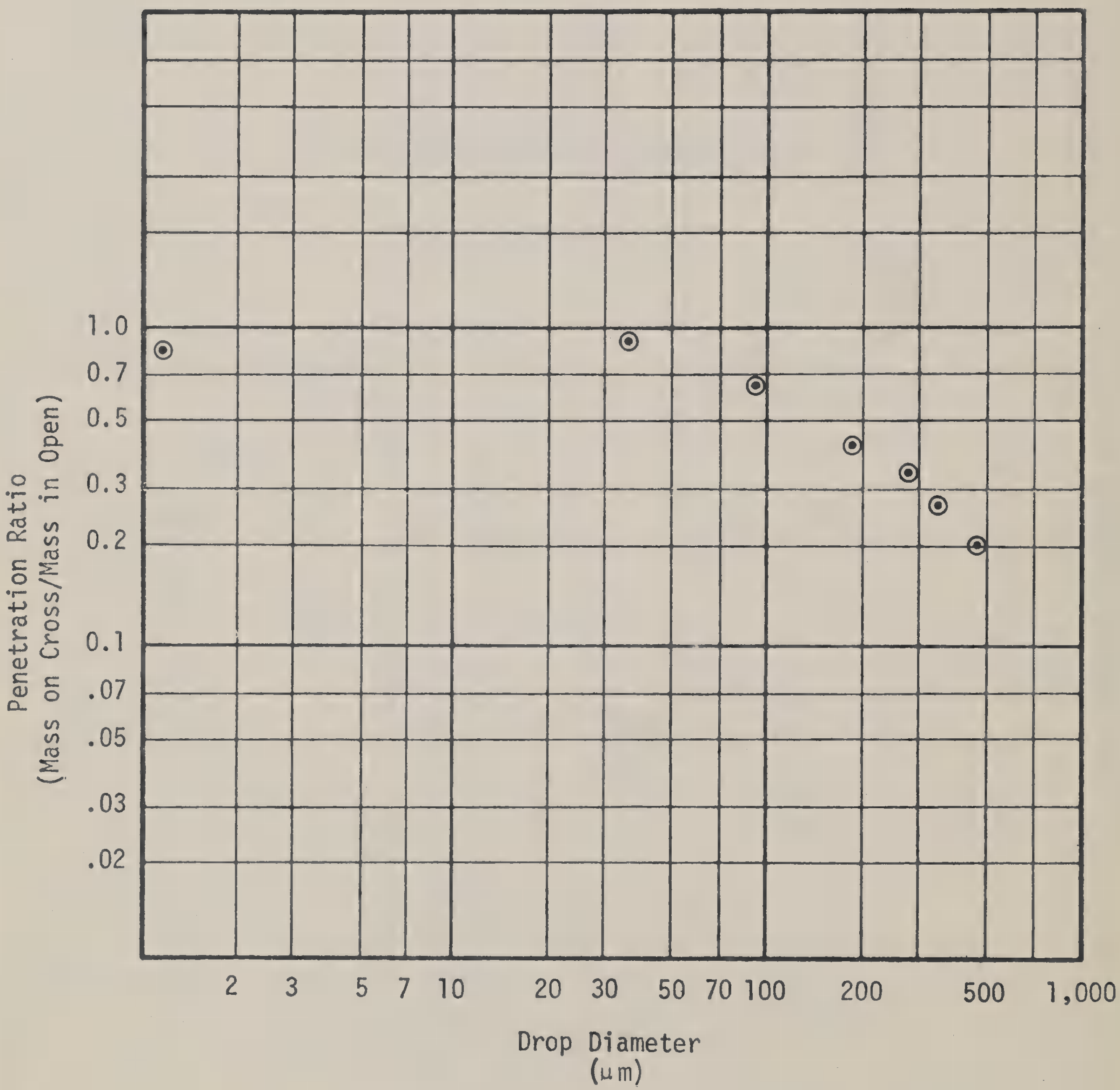
Cross-Card Data to Open-Area Data

Figures 70 Through 75



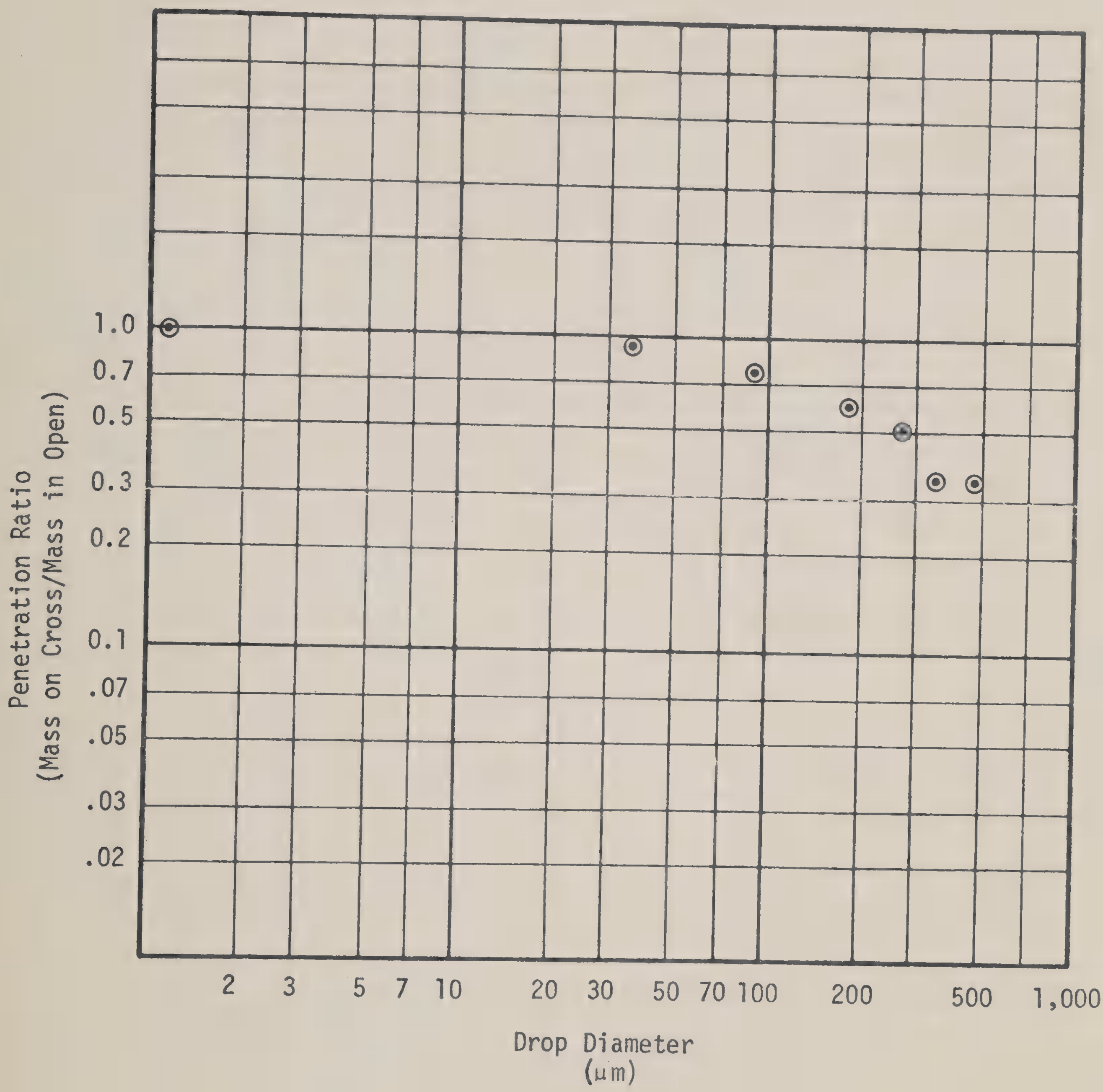
Cross Data to Open-Area Data

Figure 70. Trial B-1-1, Gash Creek



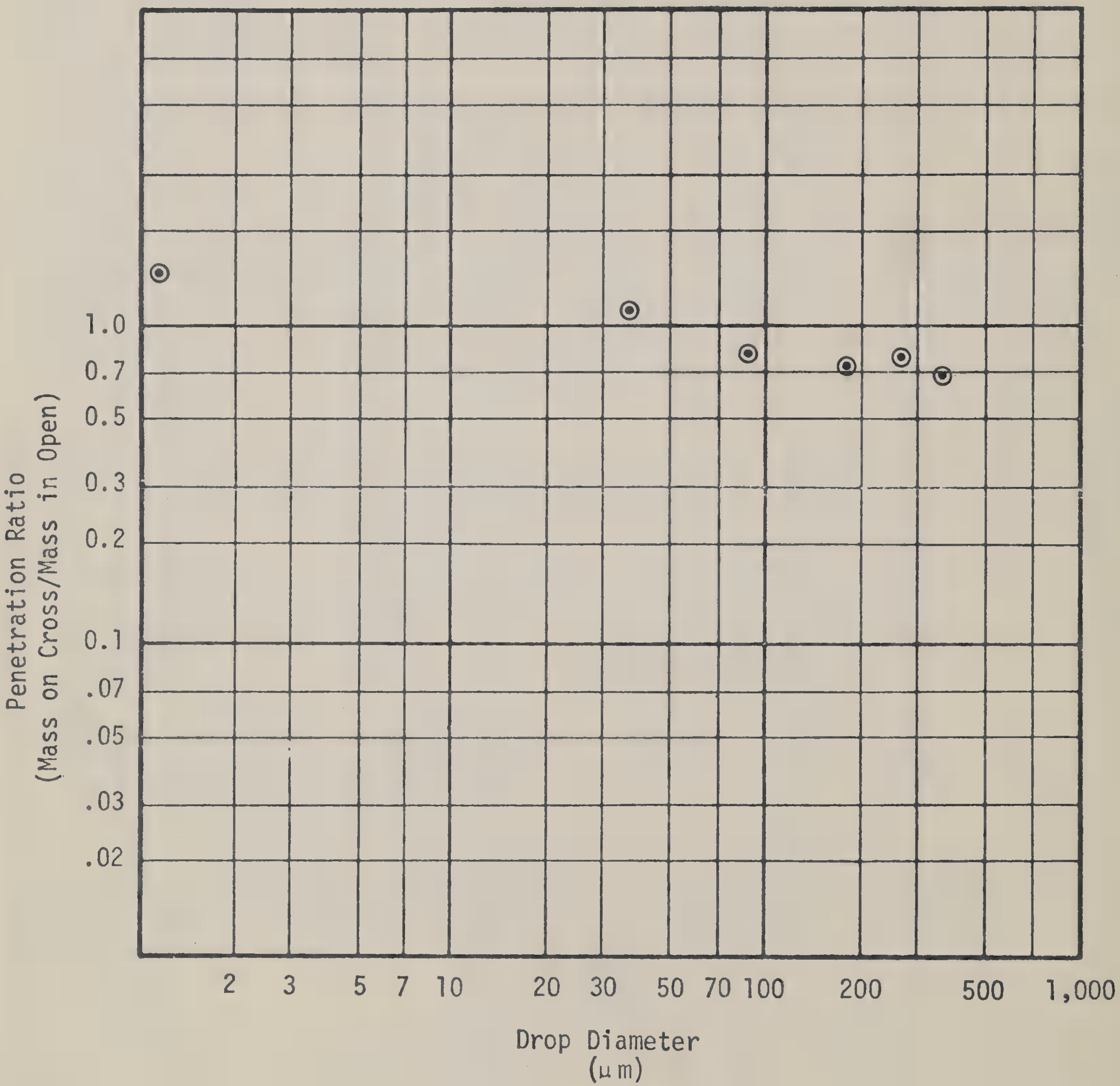
Cross Data to Open-Area Data

Figure 71. Trial B-1-2, East Sweeney Creek



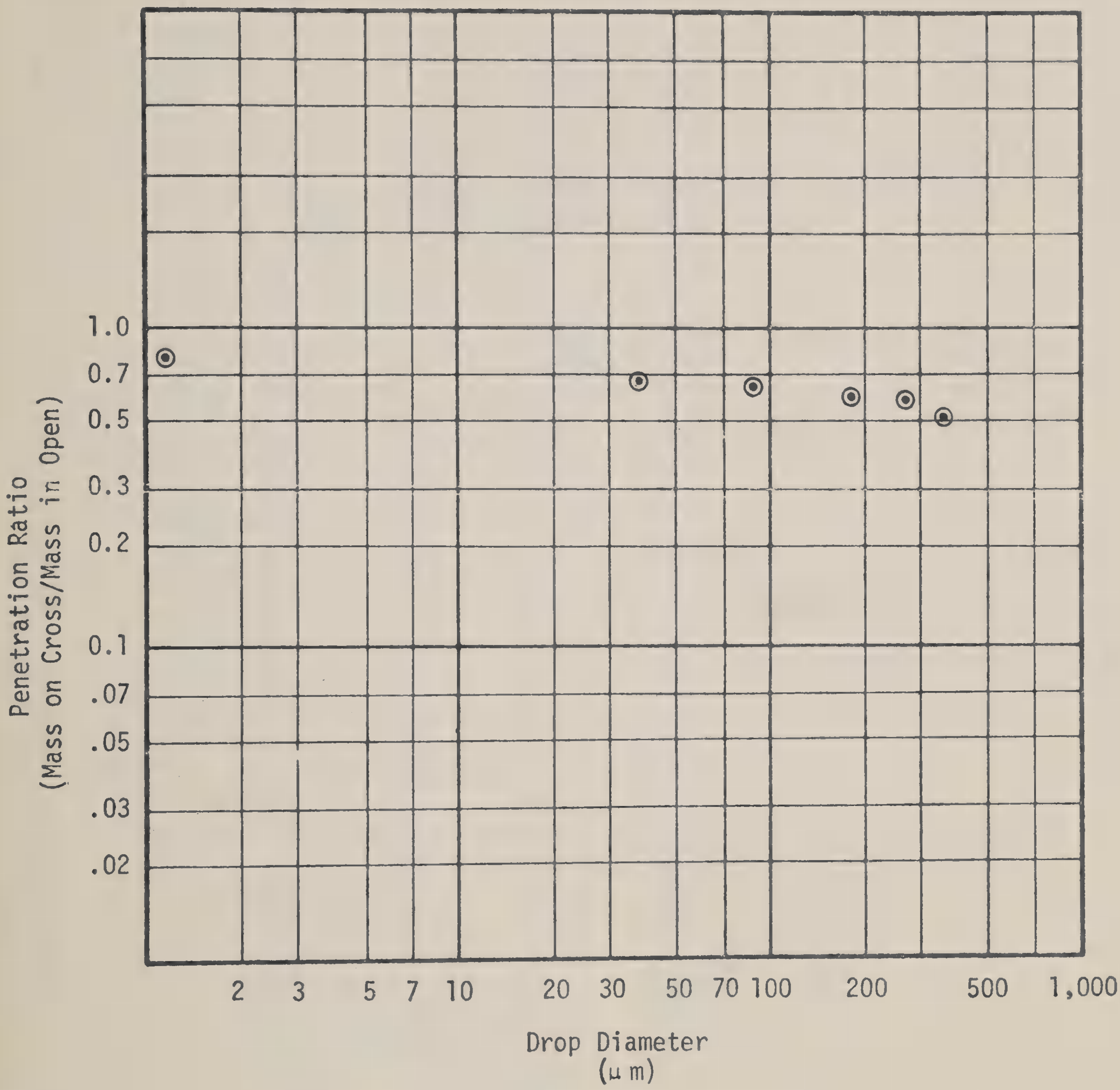
Cross Data to Open-Area Data

Figure 72. Trial B-1-3, West Sweeney Creek



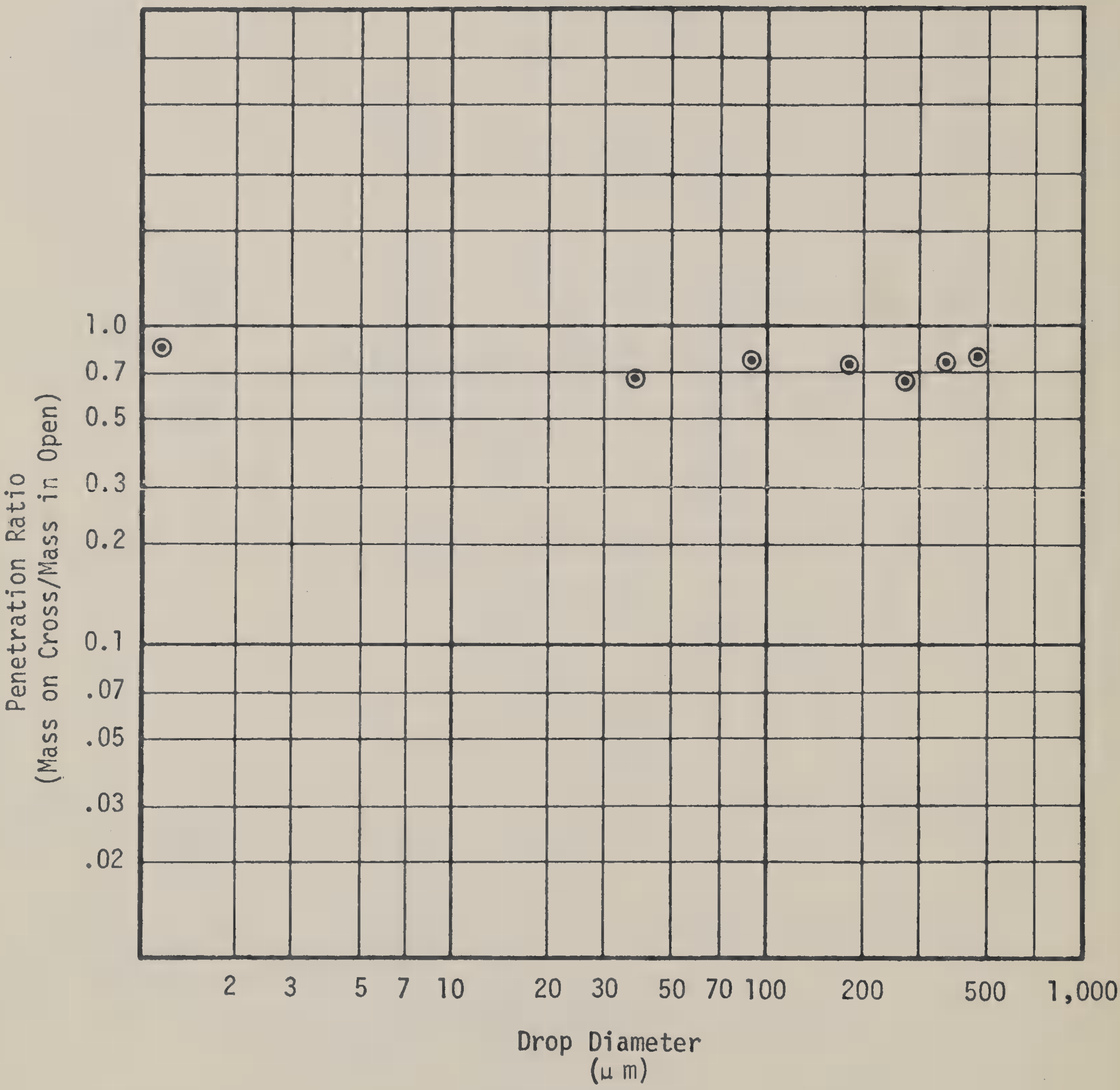
Cross Data to Open-Area Data

Figure 73. Trial B-2-4, Sawdust Gulch



Cross Data to Open-Area Data

Figure 74. Trial B-2-5, Upper Blodgett Creek



Cross Data to Open-Area Data

Figure 75. Trial B-2-6, South Bear Creek

BACILLUS THURINGIENSIS TRIALS

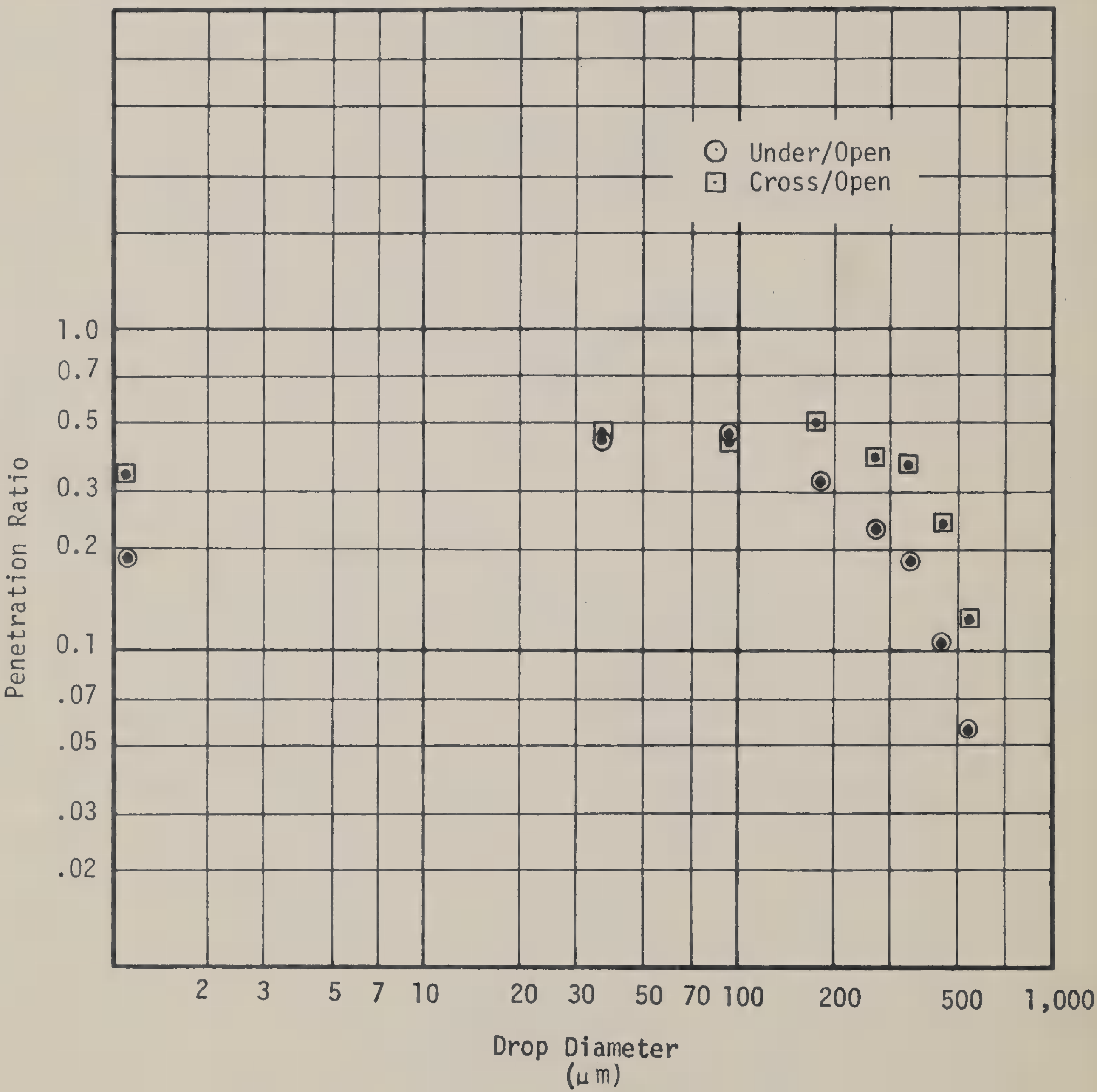
B-1-1 Through B-2-6

Canopy Penetration Ratio

Comparison of Tree Data and Cross Data

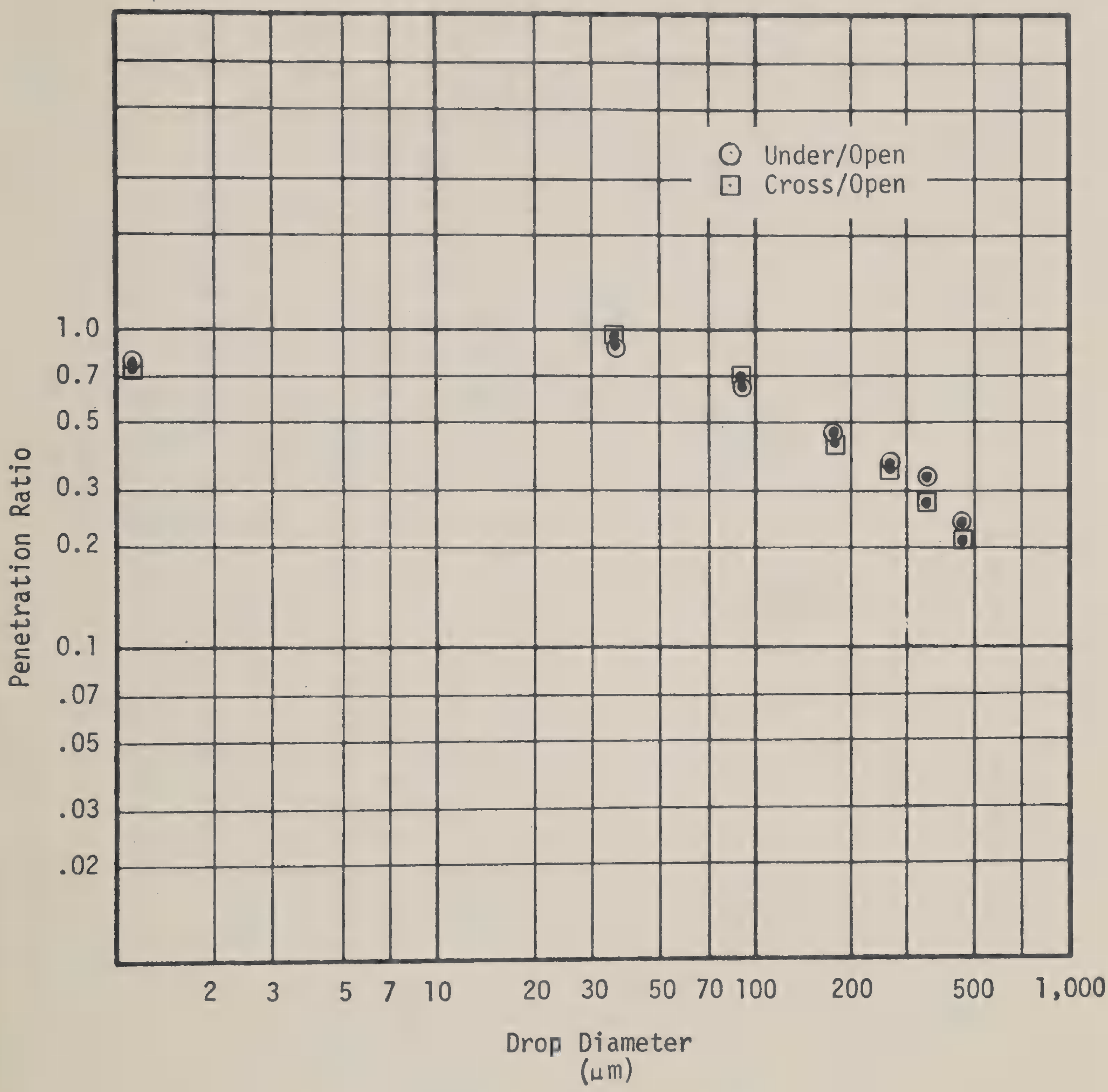
to Open-Area Data

Figures 76 Through 81



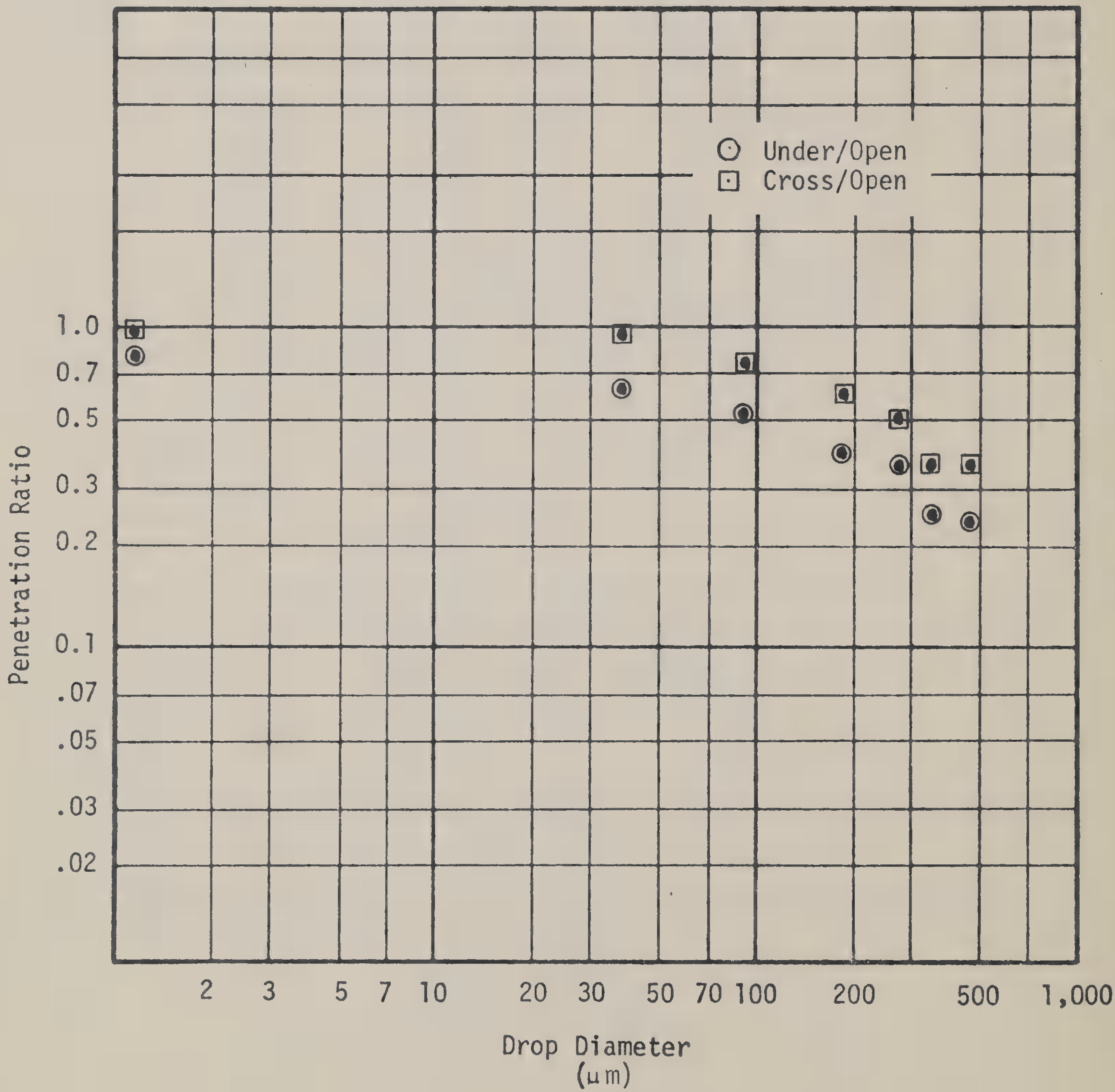
Comparison of Tree Data and Cross Data to Open-Area Data

Figure 76. Trial B-1-1, Gash Creek



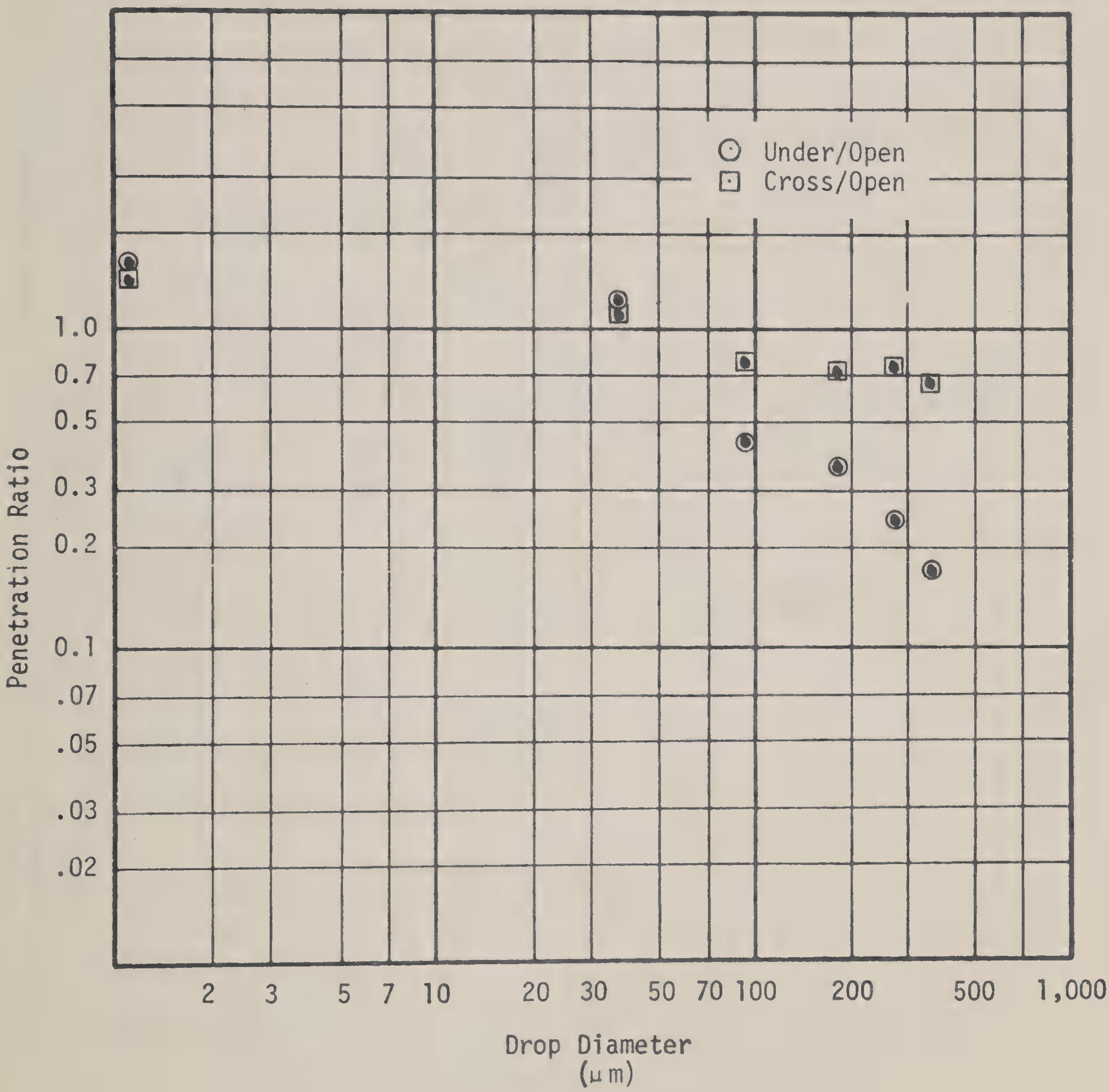
Comparison of Tree Data and Cross Data to Open-Area Data

Figure 77. Trial B-1-2, East Sweeney Creek



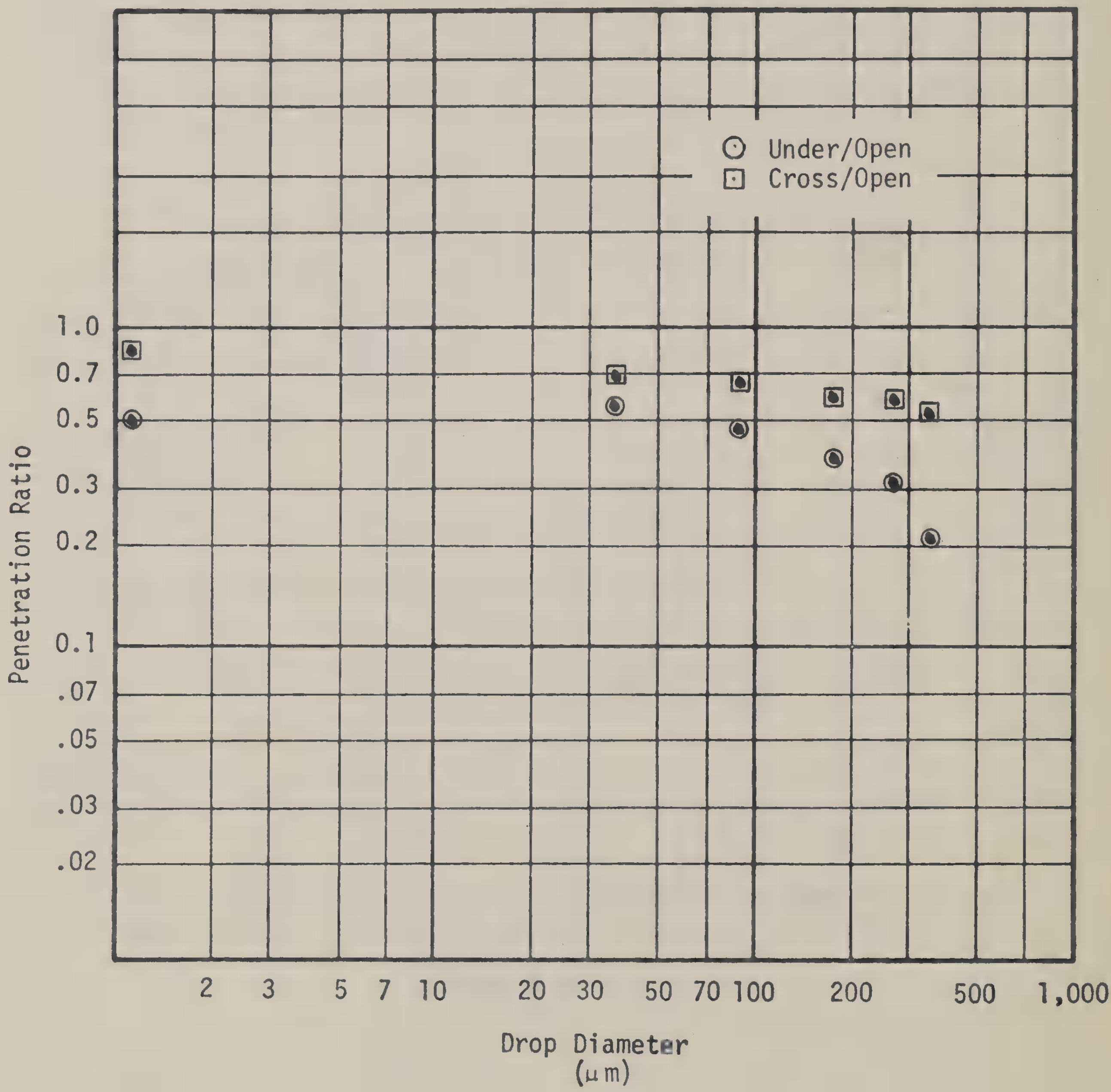
Comparison of Tree Data and Cross Data to Open-Area Data

Figure 78. Trial B-1-3, West Sweeney Creek



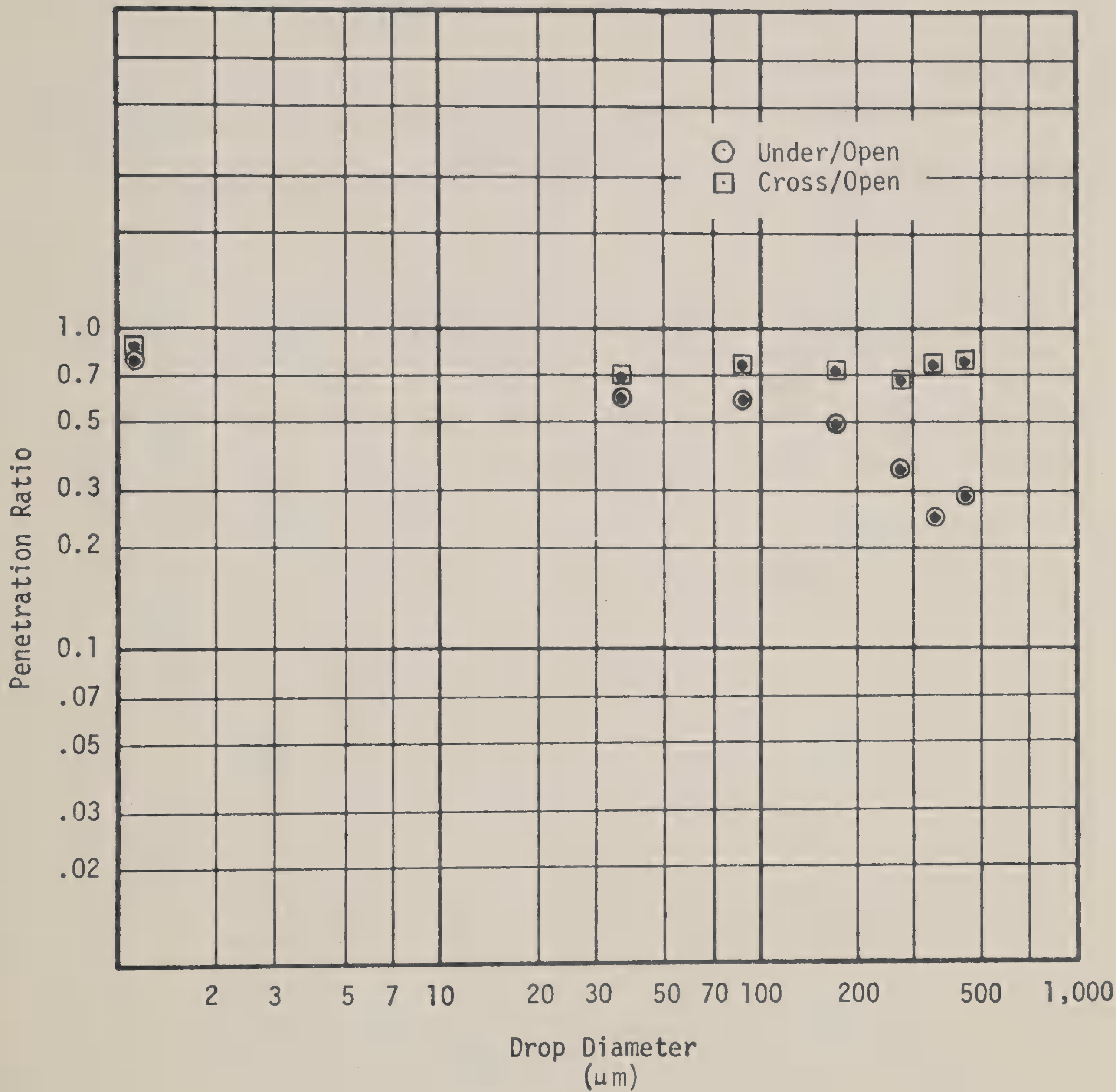
Comparison of Tree Data and Cross Data to Open-Area Data

Figure 79. Trial B-2-4, Sawdust Gulch



Comparison of Tree Data and Cross Data to Open-Area Data

Figure 80. Trial B-2-5, Upper Blodgett Creek



Comparison of Tree Data and Cross Data to Open-Area Data

Figure 81. Trial B-2-6, South Bear Creek

2.3 TASK 3. MASS DISTRIBUTION AND VOLUME MEDIAN DIAMETER

2.3.1 Objective

The objective of Task 3 was to determine mass distribution and vmd of the spray.

2.3.2 Method

Printflex sampling cards (described in Paragraph 1.8) were used to collect spray droplets for determination of mass distribution and vmd. These data were determined for each trial from groups of samplers (tree, cross, open, and drift).

2.3.3 Results

The results are given in the following Tables:

Table 39. Tree Cluster Data Trials 1 through 12 Volume Median Diameters and Mass Distribution.

Table 40. Summary Table - Trials 1 through 12 Volume Median Diameters and Mass Dis-Distribution.

Table 41. Summary of Mass Recoveries and Volume Median Diameters Beneath Sample Trees, Zectran Trials.

Table 42. Summary of Mass Recoveries and Volume Median Diameters Beneath Trees and in the Open, Bacillus thuringiensis trials.

2.3.4 Discussion

The average values shown in Tables 41 and 42 for mass recovery and vmd are consistent relative to one another. That is, the following relations hold:

mass open > mass outer ring > mass inner ring

vmd open > vmd outer ring > vmd inner ring

The difference between the inner ring and the outer ring mass and vmd is small, primarily because the trees were generally well defoliated, and in most cases, the branches near the ground were either missing or devoid of needles.

Upon examination of data from specific trials, some anomalies can be found. For example, in Trial Z-1-2, the mass and vmd of the outer ring are larger than the value in the open. This is evidently due to the unavailability of truly open areas in some of these plots.

The mass recovery in the open areas was generally well below 50 percent of the quantity disseminated. Undoubtedly, a substantial portion of the remainder, which is unaccounted for, was captured by nearby trees; however, the significance of this effect is unknown.

Table 39. Tree Cluster Data - Trials 1 Through 12

Trial	Site	Tree Cluster	Volume Median Diameter (μm)	Mass Distribution	
				(mg/m^2)	(gal/acre)
1 (Z-1-1)	Mill Creek	351-60	321	160	0.202
		361-70	316	276	0.348
		371-80	305	111	0.140
		381-90	260	129	0.163
		391-400	266	103	0.130
2 (Z-1-2)	North Bear	901-10	269	314	0.396
		911-20	282	300	0.379
		921-30	346	518	0.654
		931-40	254	159	0.201
		941-50	288	257	0.324
3 (Z-1-3)	Smith Creek	301-10	237	188	0.237
		311-20	226	118	0.149
		321-30	237	144	0.182
		331-40	243	141	0.178
		341-50	276	336	0.424
4 (Z-2-4)	Canyon Creek	1-10	363	353	0.446
		11-20	340	339	0.428
		21-30	314	289	0.365
		31-40	251	157	0.198
		41-50	241	97	0.122
5 (Z-2-5)	Lower Blodgett	701-10	257	108	0.136
		711-20	287	263	0.332
		721-30	293	320	0.404
		731-40	319	199	0.251
		741-50	289	244	0.308
6 (Z-2-6)	Big Creek	251-60	257	128	0.162
		261-70	259	106	0.134
		271-80	252	226	0.285
		281-90	256	242	0.305
		291-300	233	133	0.168

(Continued)

Table 39. Tree Cluster Data - Trials 1 Through 12 (Concluded)

Trial	Site	Tree Cluster	Volume Median Diameter (μm)	Mass Distribution (mg/m²)	Mass Distribution (gal/acre)
7 (B-1-1)	Gash Creek	1301-10	284	147	0.157
		1311-20	318	177	0.189
		1321-30	277	287	0.307
		1331-40	324	372	0.398
		1341-50	324	132	0.141
8 (B-1-2)	East Sweeney	1201-10	283	264	0.282
		1211-20	274	101	0.108
		1221-30	265	177	0.189
		1231-40	308	123	0.132
		1241-50	298	391	0.418
9 (B-1-3)	West Sweeney	1001-10	291	198	0.212
		1011-20	285	120	0.128
		1021-30	330	76	0.081
		1031-40	306	264	0.282
		1041-50	307	358	0.383
10 (B-2-4)	Sawdust Gulch	501-10	273	52	0.056
		511-20	262	116	0.124
		521-30	245	36	0.038
		531-40	231	40	0.043
		541-50	254	72	0.077
11 (B-2-5)	Upper Blodgett	801-10	275	49	0.052
		811-20	265	54	0.058
		821-30	287	75	0.080
		831-40	254	154	0.165
		841-50	264	120	0.128
12 (B-2-6)	South Bear	1501-10	266	206	0.220
		1511-20	280	362	0.387
		1521-30	314	208	0.222
		1531-40	259	214	0.229
		1541-50	271	79	0.084

Table 40. Summary Data - Trials 1 Through 12

Trial	Sample Card Location	Number Cards	vmd (μm)	gal/ acre	mg/m^2
1 (Z-1-1)	Outer[a]	188	303	0.216	171
	Inner[b]	193	293	0.181	143
	Open	40	309	0.345	273
	Cross	129	267	0.162	128
	Drift	10	243	0.114	90
2 (Z-1-2)	Outer	199	300	0.412	326
	Inner	200	293	0.370	293
	Open	37	282	0.389	308
	Cross	112	264	0.231	183
	Drift	10	256	0.068	54
3 (Z-1-3)	Outer	191	259	0.271	215
	Inner	190	238	0.198	157
	Open	39	310	0.678	537
	Cross	134	295	0.480	380
	Drift	10	306	0.288	228
4 (Z-2-4)	Outer	191	318	0.329	261
	Inner	192	316	0.298	236
	Open	39	291	0.225	178
	Cross	127	290	0.275	218
	Drift	9	218	0.135	107
5 (Z-2-5)	Outer	192	299	0.307	243
	Inner	193	284	0.263	208
	Open	40	299	0.351	278
	Cross	121	274	0.274	217
	Drift	2	154	0.025	20
6 (Z-2-6)	Outer	195	259	0.232	184
	Inner	191	243	0.189	150
	Open	40	265	0.388	307
	Cross	127	299	0.351	278
	Drift	6	301	0.482	382

(Continued)

Table 40. Summary Data - Trials 1 Through 12 (Concluded)

Trial	Sample Card Location	Number Cards	vmd (μm)	gal/ acre	mg/m^2
7 (B-1-1)	Inner	198	306	0.237	222
	Open	99	364	1.102	1031
	Cross	110	334	0.629	588
	Drift	16	267	0.058	54
8 (B-1-2)	Inner	200	288	0.227	212
	Open	98	317	0.566	529
	Cross	138	329	0.630	589
	Drift	4	353	0.146	137
9 (B-1-3)	Inner	198	304	0.218	204
	Open	97	329	0.630	589
	Cross	115	334	0.442	413
	Drift	13	343	0.313	293
10 (B-2-4)	Inner	194	256	0.068	64
	Open	100	303	0.248	232
	Cross	139	295	0.174	163
	Drift	12	284	0.074	69
11 (B-2-5)	Inner	200	265	0.096	90
	Open	99	300	0.294	275
	Cross	125	299	0.181	169
	Drift	10	322	0.251	235
12 (B-2-6)	Inner	191	276	0.228	213
	Open	100	313	0.577	540
	Cross	118	315	0.426	398
	Drift	8	336	0.233	218

[a] Inner sample-card location refers to sampler position halfway between the trunk and tree drip line.

[b] Outer sample-card location refers to sample position at the tree drip line.

Table 41. Summary - Mass Recoveries and Volume Median Diameters Beneath Sample Trees and in Open - Zectran Trials [a]

Trial	Mass Recovery (gal/acre)			Volume Median Diameter (μm)		
	Outer Ring	Inner Ring	Open Area	Outer Ring	Inner Ring	Open Area
Z-1-1	0.216	0.181	0.345	303	293	309
Z-1-2	0.412	0.370	0.389	300	293	282
Z-1-3	0.271	0.198	0.678	259	238	310
Z-2-4	0.329	0.298	0.225	318	316	291
Z-2-5	0.307	0.263	0.351	299	284	299
Z-2-6	0.232	0.189	0.388	259	243	265
Average	0.295	0.250	0.396	290	278	293

[a]Spray applied at 1 gallon per acre.

Table 42. Summary - Mass Recoveries and Volume Median Diameters Beneath Sample Trees and in Open - Bt. Trials [a]

Trial	Mass Recovery (gal/acre)		Volume Median Diameter (μm)	
	Inner Ring	Open Area	Inner Ring	Open Area
B-1-1	0.237	1.102	306	364
B-1-2	0.227	0.566	288	317
B-1-3	0.218	0.630	304	329
B-2-4	0.068	0.248	256	303
B-2-5	0.096	0.294	265	300
B-2-6	0.228	0.577	276	313
Average	0.179	0.570	283	321

[a]Spray applied at 2 gallons per acre.

2.4 TASK 4. DEPOSITION SAMPLING

2.4.1 Objective

The objective of Task 4 was to evaluate the optimum method for deposition sampling of sprayed materials for operational control projects, pilot tests, and field experiments.

2.4.2 Method

Deposition sampling cards were placed at various locations within and along the periphery of the spray plot. Approximately 650 cards were used in each trial, positioned as shown in Figures 33 and 34.

2.4.3 Results

Results are shown in Tables 39 and 40.

2.4.4 Discussion

The task objectives will dictate the location and placement of deposition cards within the spray area. Generally, one of the following objectives will be appropriate:

a. To determine qualitatively the spray coverage throughout the spray plot or area.

b. To determine quantitatively the amount of spray material deposited on trees specified for insect mortality studies (dosage and insect mortality correlations.)

c. To determine quantitatively the amount or mass and the droplet size of the spray material which penetrates the forest canopy.

d. To determine qualitatively spray drift.

The number of deposition cards used on a particular project will also be dependent upon the objectives of the project and upon available resources.

Based upon the data obtained on this test recommendations for sampling on three types of spray projects (control, pilot, field experiment) are presented in Table 43.

The printflex card used during this test measured 6 5/8 by 8 5/8 inches; the card was held in a stainless steel holder. The results obtained from the cards were considered highly satisfactory for the dye sprays used in the test. The card holder, however, was considered too bulky and too heavy for backpacking over forest terrain. This holder was rated unsatisfactory.

Deposition samplers used in open areas for the purpose of obtaining a representative open-area sample should be positioned at least three tree heights from the closest tree.[6] This cannot always be accomplished due to the nature of the spray area. An alternative method is to disseminate the spray material from the helicopter while flying at a right angle over several lines of deposition cards in the open. The spray altitude should approximate the normal spray altitude over the target.

Deposition samplers placed beyond the periphery of the spray plot can be used, as in this test, to qualitatively determine drift. However, the large droplets within a drift cloud soon fall out, while

Table 43. Recommended Methods for Deposition Sampling on Forest Spray Projects Using Printflex or Kromekote Cards

Purpose	Position of Samplers	Type Spray Project
1. To determine qualitatively the spray coverage throughout the spray plot or area.	Two sampling lines which cross at right angles at center of plot. Spacing would be dependent upon plot size.	Control Projects Pilot Tests Field Experiments
2. To determine quantiatively the amount of spray material deposited at trees specified for insect mortality studies for the purpose of making dosage and insect mortality comparisons.	Four samplers at the cardinal position beneath the designated sample tree and halfway between the drip line and trunk of the tree, assuming uniform coverage of the spray area	Control Projects Pilot Tests Field Experiments
3. To determine quantitatively the amount or mass of the spray material and the droplet size which penetrated the forest canopy. This is a comparison of recoveries under the trees or on the cross sampling lines to recoveries in the open.	Several (40-50) samplers placed in open areas within the spray plot. The open areas must be outside the screening effect of trees (minimum three tree heights from the nearest tree).	Pilot Tests Field Experiments
4. To determine qualitatively spray drift outside the spray plot.	Samplers should be place at 50-foot intervals downwind at least 1,000 feet beyond the last spray swath	Control Projects Pilot Tests
5. To determine quantitatively the spray mass and vdm at designated vertical heights within the forest to evaluate spray deposition as a function of height to the canopy.	Samplers can be placed on a tower, on tree branches, or on tethers of a balloon.	Field Experiments

the finer droplets continue to drift. Other types of samplers are necessary to obtain quantitative data on that portion of the spray cloud which drifts beyond the target site.

2.5 TASK 5 MATHEMATICAL MODEL PREDICTIONS

2.5.1 Objective

The objective of Task 5 was to compare model predictions of deposition at ground level in forest clearings with actual recoveries obtained in field trials at ground level in forest clearings.

2.5.2 Method

A mathematical prediction model was used to obtain estimates of the amount of Zectran and Bt. deposited at ground level in forest clearings. The deposition model used in the calculations was a simplified version of the generalized deposition and concentration models developed for use with aerial spray releases over unforested, flat terrain (see Cramer, et al., 1972).[6] The generalized models have proved effective in predicting deposition and air concentrations under conditions discussed by Cramer.

The models used in this study were essentially tilted-plume models.[7] The inclination of the cloud axis from the horizontal is given by $\tan^{-1} V_s/\bar{u}$, where V_s is the settling velocity for a particular droplet size category and $\bar{u}$ is the mean transport wind speed. In all cases, material released into the atmosphere in the surface mixing layer and dispersed upward by turbulence is assumed to be reflected downward at the top of the surface mixing layer. Material intersecting the top of the forest canopy or impacting on the ground is assumed to deposit without reflection. The basic models are used to calculate a deposition or concentration pattern for a single droplet size category and for a

single release line (swath). The total deposition and concentration patterns are obtained by summing the results for all droplet size categories representative of the full distribution of droplet sizes comprising the source and for all swaths downwind from the upwind edge of a treatment block.

In applying the models to forest canopies, the assumption was made that the meteorological structure affecting deposition and diffusion generally "follows" the slope of the terrain. For example, the depth of the surface mixing layer was assumed to be the same everywhere above a sloping surface. It also was assumed that the helicopter would fly release lines along the slope (crosswind), beginning at the downslope side of the treatment block and repeating the release line in upslope increments or swath widths of 63 feet. Further, the downdraft caused by the helicopter, which flew about 50 feet above the canopy at a speed of 45 miles per hour, was assumed to be ineffective in reducing the source height. However, the atmospheric turbulence level, which was usually low in the surface mixing layer during early morning hours when tests were conducted, was increased in consideration of the turbulent wake effect caused by the helicopter passage. The effect of these assumptions influenced the deposition and concentration estimates for several hundred meters downwind from each swath. Beyond these distances the insecticide cloud from each swath fills the turbulent mixing layer, and the above assumptions will not affect the calculations.

In order to compute an average percent recovery of the material sprayed during the trials, a comparison was made between the predicted value of ground deposition density in the open and actual ground deposition densities obtained in open areas within the forest.

The input parameters used in the model were approximations to the conditions existing during the field trials. Droplet size spectrum information for both Zectran in oil and Bt. in water were obtained from printflex card data obtained in the trials and were used as model input.

The open areas used in these trials were not truly open in that they were simply the best open areas available. Ideally a completely cleared area adjacent to the forested plots would represent the optimum open condition. In view of the fact that the open areas used in the trials were often influenced by nearby trees, only "open" cards with deposition density levels above the median deposition density level of all the "open" cards were used in computing the average deposition density level for each of the trials.

Plots were constructed for each set of trials, one for the Zectran trials and one for the Bt. trials. Each plot shows the predicted deposition of the spray, the average deposition for each trial, and deposition recoveries obtained on cards positioned downwind and beyond the periphery of the plot.

2.5.3 Results

2.5.3.1 Percent Recovery

As can be seen from the model output curves in Figures 82 and 83 the ground deposition density level reaches a plateau approximately halfway down the grid. The average deposition density levels of the open cards as computed with the procedure stated above were therefore plotted at the midpoint of the grid.

Percent recoveries for the oil-based trials range from 20 to 50 percent of the total material sprayed.

Percent recoveries for the water-based trials range from 50 to 75 percent of the total material sprayed.

2.5.3.2 Downwind Drift

Figures 82 and 83 also depict the measured downwind drift samples and the model prediction for downwind drift. The field recoveries tend to fall off more rapidly than the model predicted.[7] This could be due to several factors:

a. The influence of trees acting as collectors on the downwind drift samples.

b. A larger portion of the original aerosol remains airborne than the model predicts. The droplets which compose the drift cloud are small with a low fall velocity and consequently settle very slowly, are difficult to collect and detect on deposition cards, and (in this test) would settle at locations beyond the sampling stations.

c. The sample size was rather small and may not be representative of the overall drift.

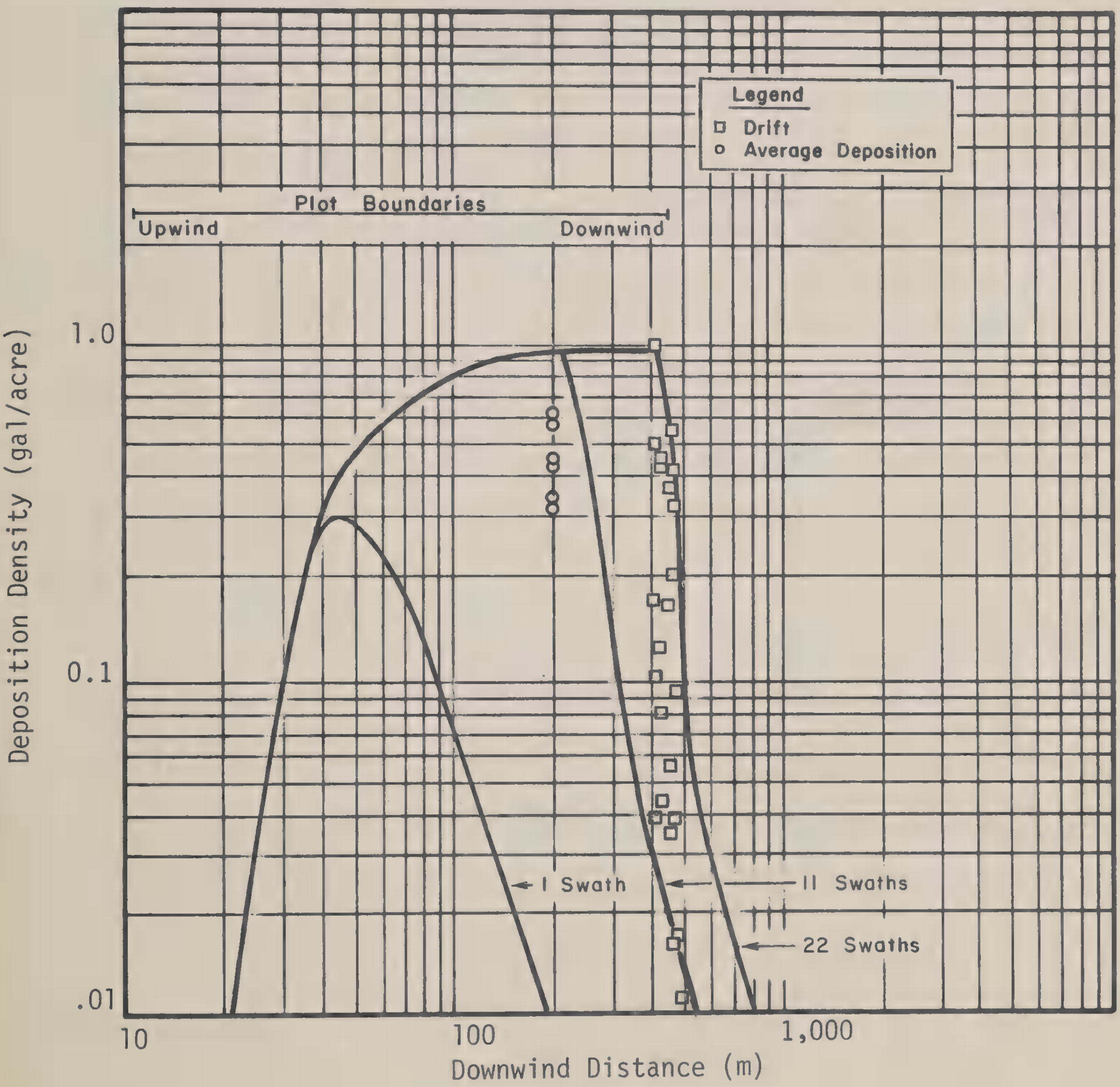


Figure 82. Droplet Distribution from Calibration Run in Open (Spray - 1 gallon per acre oil base; Swaths - 18 meters Wind Speed - 1 meter per second)

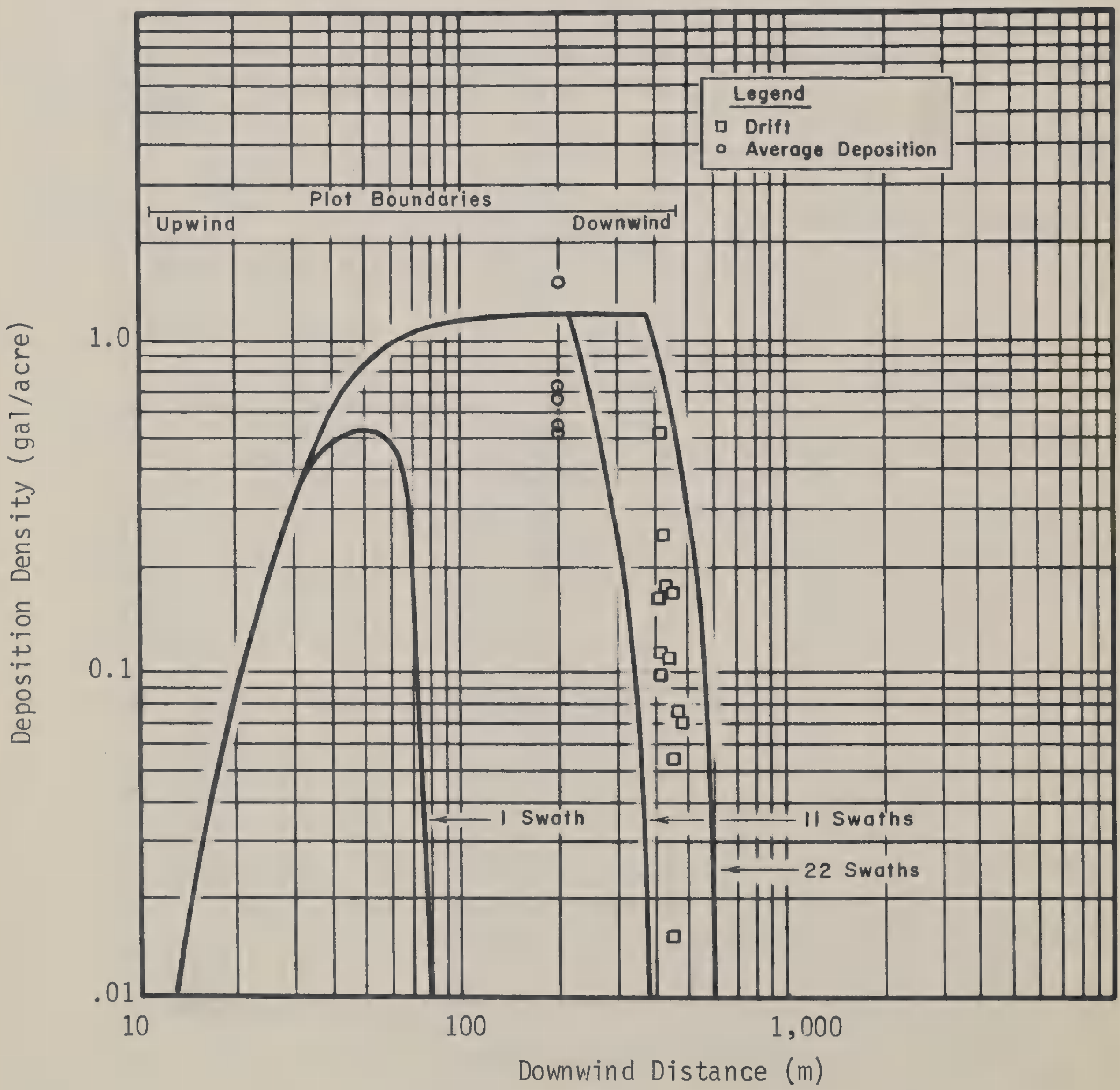


Figure 83. Droplet Distribution from Calibration Run in Open (Spray - 2 gallons per acre water base; Swaths - 18 meters; Wind Speed - 1 meter per second)

2.6 TASK 6 HELICOPTER SPRAY SWATHS

2.6.1 Objective

The objective of Task 6 was to monitor the accuracy of helicopter swathing.

2.6.2 Method

Three transit locations, each manned by two persons, were established within the Smith Creek and Big Creek plots. The position of the helicopter was determined simultaneously at each of the three locations during each release (swath) by the helicopter. These positions were plotted on a map, assuming, for the purpose of the exercise, that each swath was parallel to the first swath. The helicopter was not in view of all three transit locations during each pass; consequently, a few passes were missed.

2.6.3 Results

The plottings (Figures 84 and 85) show the three transit locations and the position of the helicopter at one location during each passage (swath). These helicopter positions were plotted as parallel swaths. It is obvious that the helicopter pilot experienced considerable difficulty in estimating swath widths. For example, on the Smith Creek Trial, spray runs 8, 10, 12 and 15 were conducted virtually over the same terrain, and run Number 5 was between terrain covered in runs 1 and 3.

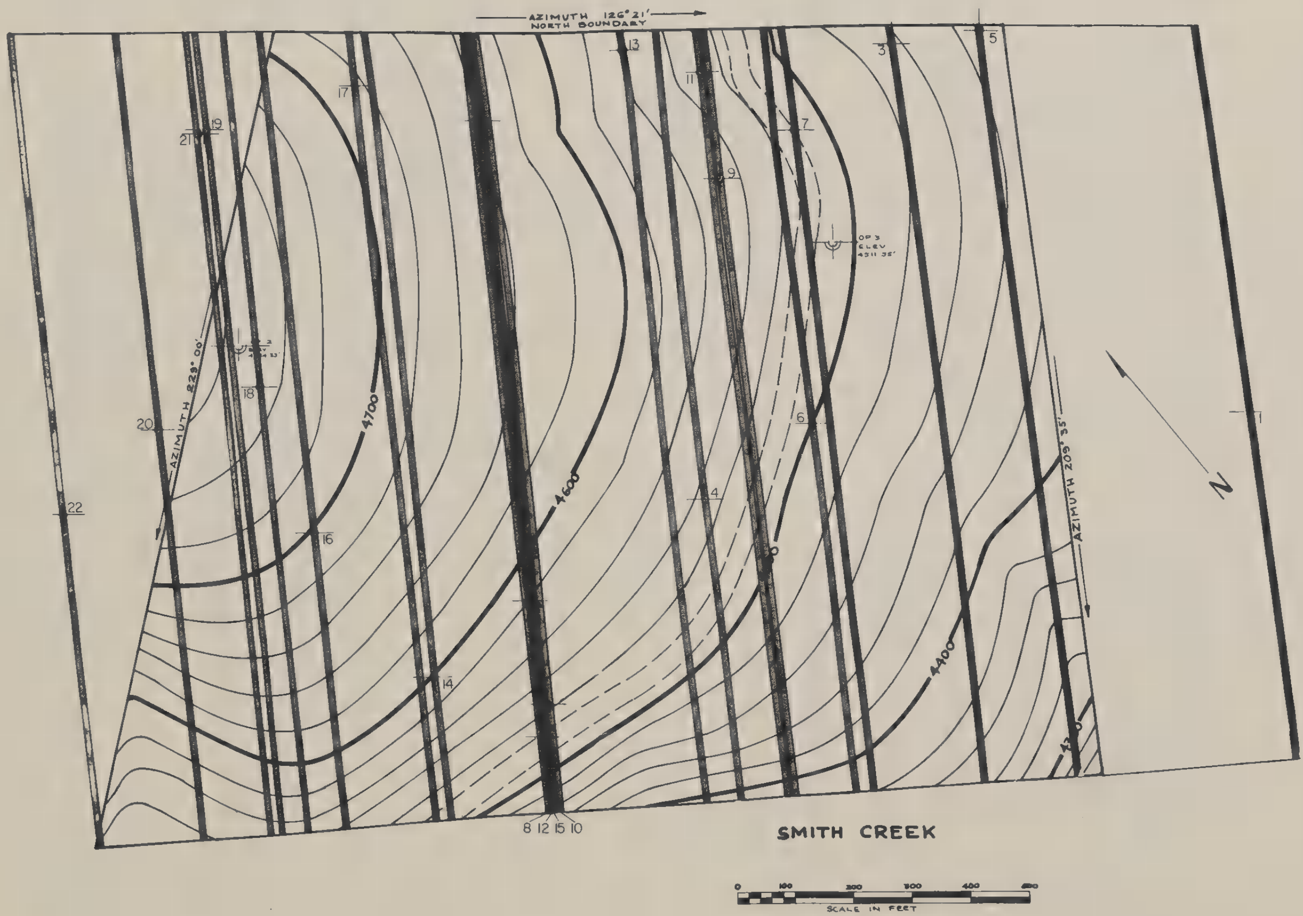


Figure 84. Smith Creek Plot: Transit Observation Positions and Helicopter Swaths

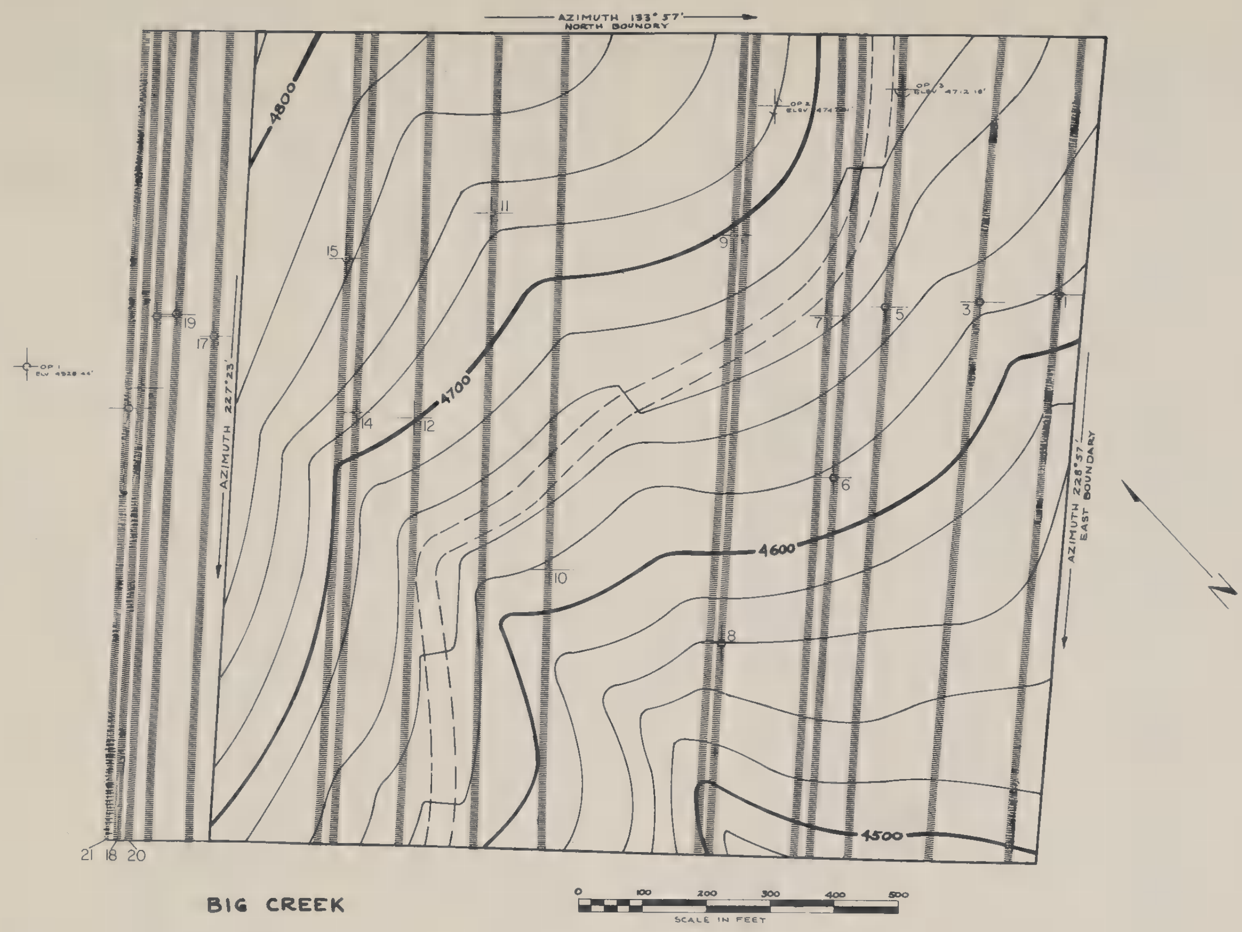


Figure 85. Big Creek Plot: Transit Observation Positions and Helicopter Swaths

2.6.4 Discussion

The trials were well controlled and coordinated. The pilots were given a thorough briefing including air and general reconnaissances prior to the test. To insure that the pilot could correctly orient his position, each corner of the spray plot was marked with colored flagging, and colored smoke grenades were employed to mark plot centers. In addition to these measures a flagman was employed to assist the pilot in estimating the swath spacing.

Under normal spray operations spray blocks are not marked to the extent as described for this test. It is neither practical nor desirable to expend the resources necessary for clearly marking large spray areas.

The purpose of the extensive marking was to determine how precisely a spray pilot can spray a well defined target under nearly ideal conditions. The results clearly demonstrated that the spraying of the two plots was imprecise even when conducted by experienced, well oriented pilots flying over clearly marked and well defined sites.

APPENDIX A. REFERENCES

1. US Department of Agriculture, Forest Service, Northern Region, Missoula, MT. A Pine Butterfly Impact Survey on the Bitterroot National Forest and State of Montana Lands, by Jerald E. Dewey, et al. Report No. 73-12, 1973.

2. U.S. Department of Agriculture, Forest Service Region 1. Study Plan, Field Experiment on Insecticides on Pine Butterfly Populations, Bitterroot National Forest, Montana, 1973.

3. US Department of Agriculture, Forest Service, Northern Region, Missoula, MT. Mexacarbate and Bacillus thuringiensis for Control of Pine Butterfly Infestations - Bitterroot National Forest, Montana - 1973, by Jerald E. Dewey, et al. Report No. 74-10, 1974.

4. Memorandum of Understanding between US Army Materiel Command and US Forest Service, April 1973, and Supplemental Agreement No. 1 to Memorandum, May 1973, subject: Deseret Test Center Support of U.S. Forest Service Pine Butterfly Test Bitterroot National Forest.

5. U.S. Department of Agriculture, Forest Service, Missoula Equipment Development Center, Missoula, MT. Spray Deposit Assessment Systems, ED&T Proposal Nos. 2353 and 2425, January 1972.

6. Deseret Test Center, Fort Douglas, UT. Development of Dosage Models and Concepts, by H. E. Cramer, et al. Prepared by GCA Corporation, Bedford, MA, contract DAAD09-67-C-0020(R). Report No. DTC-TR-72-609, 1973.

7. Maksymiuk, Bohdan, "Screening Effect of the Nearest Tree on Aerial Spray Recovered at Ground Level," Journal of Forestry, Vol 61, No. 2, 1963

8. US Army Dugway Proving Ground, Dugway UT. Model Estimates of Deposition and Concentration for the 1973 Field Test of Insecticides on Pine Butterfly Larval Population in the Bitterroot National Forest, by K. E. Dumbauld and H. E. Cramer. Prepared by H.E. Cramer Company, Inc., Salt Lake City, UT. 1973 (Unpublished)

APPENDIX B. PHOTOGRAPHS OF SELECTED SAMPLE TREES

Figure B-1. Tree No. 915

Figure B-2. Tree No. 918

NORTH BEAR CREEK TRIAL (Z-1-2)

Figure B-3. Tree No. 941

Figure B-4. Tree No. 944

NORTH BEAR CREEK TRIAL (Z-1-2)

Figure B-5. Tree No. 948

NORTH BEAR CREEK TRIAL (Z-1-2)

Figure B-6. Tree No. 302

Figure B-7. Tree No. 303

SMITH CREEK TRIAL (Z-1-3)

Figure B-8. Tree No. 342

Figure B-9. Tree No. 346

SMITH CREEK TRIAL (Z-1-3)

Figure B-10. Tree No. 349

SMITH CREEK TRIAL (Z-1-3)

Figure B-11. Tree No. 701

Figure B-12. Tree No. 710

LOWER BLODGETT CREEK TRIAL (Z-2-5)

Figure B-13. Tree No. 746

Figure B-14. Tree No. 747

LOWER BLODGETT CREEK TRIAL (Z-2-5)

Figure B-15. Tree No. 750

LOWER BLODGETT CREEK TRIAL (Z-2-5)

Figure B-16. Tree No. 285

Figure B-17. Tree No. 288

BIG CREEK TRIAL (Z-2-6)

Figure B-18. Tree No. 289

Figure B-19. Tree No. 291

BIG CREEK TRIAL (Z-2-6)

Figure B-20. Tree No. 295

BIG CREEK TRIAL (Z-2-6)

Figure B-21. Tree No. 1338

Figure B-22. Tree No. 1339

GASH CREEK TRIAL (B-1-1)

Figure B-23. Tree No. 1340

Figure B-24. Tree No. 1342

GASH CREEK TRIAL (B-1-1)

Figure B-25. Tree No. 1343

GASH CREEK TRIAL (B-1-1)

Figure B-26. Tree No. 1204

Figure B-27. Tree No. 1205

EAST SWEENEY CREEK TRIAL (B-1-2)

Figure B-28. Tree No. 1208

Figure B-29. Tree No. 1214

EAST SWEENEY CREEK TRIAL (B-1-2)

Figure B-30. Tree No. 1007

Figure B-31. Tree No. 1009

WEST SWEENEY CREEK TRIAL (B-1-3)

Figure B-32. Tree No. 1012

Figure B-33. Tree No. 1017

WEST SWEENEY CREEK TRIAL (B-1-3)

Figure B-34. Tree No. 1019

WEST SWEENEY CREEK TRIAL (B-1-3)

Figure B-35. Tree No. 835

Figure B-36. Tree No. 836

UPPER BLODGETT CREEK TRIAL (B-2-5)

Figure B-37. Tree No. 838

Figure B-38. Tree No. 849

UPPER BLODGETT CREEK TRIAL (B-2-5)

Figure B-39. Tree No. 850

UPPER BLODGETT CREEK TRIAL (B-2-5)

Figure B-40. Tree No. 1536

Figure B-41. Tree No. 1537

SOUTH BEAR CREEK TRIAL (B-2-6)

Figure B-42. Tree No. 1541

Figure B-43. Tree No. 1542

SOUTH BEAR CREEK TRIAL (B-2-6)

Figure B-44. Tree No. 1543

SOUTH BEAR CREEK TRIAL (B-2-6)

APPENDIX C. CREW INSTRUCTION SHEETS AND SCHEDULE OF EVENTS

PRINTFLEX CREW INSTRUCTIONS

1- THE NORTH POSITION AT EACH SAMPLE TREE HAS BEEN MARKED WITH A STAKE.

2- CARDS WILL BE PLACED AT THE SAMPLING POSITIONS IN THE STAINLESS STEEL CARD HOLDERS.

3- CARDS MAY BE MARKED BEFORE OR AFTER THE TRIAL WITH BALLPOINT PEN.

4- WHEN PICKING UP THE CARDS BE SURE NOT TO TOUCH THE FACE OF THE CARD AS THIS WILL SMEAR THE OIL STAINS.

5- AFTER THE TRIAL, START PICKING UP THE CARDS NO SOONER THAN ONE HOUR AFTER THE SPRAYING IS COMPLETED ON YOUR SPRAY BLOCK.

6- LEAVE THE CARDS IN THE STEEL HOLDERS AND STACK IN THE BOXES. BE SURE THAT YOU KEEP THE BOXES SEPARATED FROM THOSE OF THE OTHER CREWS.

7- PLACE DUST COVERS (PLASTIC BAGS) OVER THE BOXES.

8- DELIVER THESE CARDS TO JACK BARRY AT THE STEVENSVILLE LABORATORY.

MATERIALS REQUIRED

- CARDS
- CARD HOLDERS
- COMPASS
- BALL POINT PENS
- PACK OR CARRIER FOR HOLDERS

PLOT NAME: ________________ TEAM LEADER: ________________
TRIAL NO. ________________
DATE: ________________

NOTE: Indicate on diagram

1--Magnetic North
2--Wind direction at spray time
3--Downhill direction
4--Sample card numbers
5--Tree numbers
6--Location of sample cards

Spray offset: ______________
Time spray start: ___________
Time spray stop: ___________
Wind direction ____________

REMARKS:

PRINTFLEX CARD NUMBERING

There are three different kinds of cards from 12 trials.

I. Tree cards

II. Cross sampling cards

III. Open area sampling cards

At the request of the Chemical Assay Personnel, the cards were renumbered as follows:

I. Tree Cards

	Trial Number	Tree Numbers
	1	351-400
	2	901-950
Zectran	3	301-350
Oil Red	4	1- 50
	5	701-750
	6	251-300
	7	1301-1350
	8	1201-1250
	9	1001-1050
	10	501- 550
	11	801- 850
	12	1501-1550

Therefore, a number 801-1 would be tree number 801 (from trial 11) and position 1 or the north position beneath the tree.

II. Cross sampling cards. These cards are marked according to trial number and location i.e.

1 — 50

Trial Number   Location

III. Open area sampling cards. These cards are marked by trial number, by location and sequence.

INSTRUCTIONS FOR
PRINTFLEX CARD SAMPLING ON THE Bt TESTS

1. The outer ring of cards will be eliminated for the Bt plots. Therefore, cards E, F, G, and H only will be used at the sample trees. (Total cards = 200.)

2. One hundred (100) cards will be placed randomly in open areas throughout the plot. (Total cards = 100.)

3. The cross-sampling lines will be extended 160 feet at each end of the line. (Total cards = 149.)

4. Total Printflex cards for each Bt plot is 449.

5. The water spray has been dyed with a water-soluble spray called Rhodamine B extra S. This dye gives a red color to the spray which will appear similar to the dyed Zectran spray. Rhodamine fades rapidly in sunlight. Therefore, it is essential that the cards be picked up immediately after spraying. The cards exposed to sunlight should be picked up first.

6. Do not touch the cards. The spray to which you will be exposed contains a harmless bacterial spore and a fluorescent tracer. Your clothing and hands will be contaminated; therefore, you must avoid contaminating the sample cards with bacterial spores and fluorescent tracer from the previous day's spray.

7. All personnel should remain in closed vehicles during the spray and preferably outside the spray plot.

8. You should bathe thoroughly before the second test day and wear a clean set of clothing to reduce contamination of the second day samplers.

9. All sample cards should be marked prior to setout on the plot according to the marking system used on the Zectran plots. The first Bt plot will be numbered 1 and the last 6, same as the Zectran.

10. After the test, cover the cards in clean plastic bags and return to the Stevensville Lab.

Bt TEST, BITTERROOT, 1973

COLLECTION OF NEEDLE SAMPLE FOR BIOLOGICAL AND FP ASSAY

1. Ponderosa needle sampling will be performed on each Bt plot by a special sampling crew at two different periods after spraying. The first sample will be taken the afternoon of the first spray day and the second sample will be taken eight days after spraying.

2. Ten controls will be collected at the Bt control plot on each sample day from randomly selected sample trees.

3. Two samples, each consisting of a three needle cluster, will be collected from each of the 50 sample trees at the north and south end of the tree at approximately mid-crown level. A special pole pruner will be used which will hold the collected sample freely in the air, thus avoiding contamination with other surfaces. The sample will be placed in the plastic screw cap vial in the manner as illustrated on the attached diagram.

4. Sample marking:

   a. Controls

      C - 1 - 1

      Control

      Plot No.

      Sample Sequence No.

   b. Test Plot

      1 - 501 - N

      Plot No.

      Tree No.

      Location on tree (S for south side of tree)

5. It is extremely important to avoid contaminating the samples. After spraying, the spores and FP will cover all surfaces within the plot. The greatest chance of contamination will be from touching the needles and cross-contamination with the scissors from sample to sample.

6. After the samples are collected they will be placed in a box for delivery to Jack Barry, MEDC.

Bt TEST SCHEDULE

Date	Time	Event
14 June 73 Thursday	0900	Team leaders mark test plots on photographs at Engineering
	1225	Meteorological team arrives from DTC
	1400	Met team surveys test plots
	1500	Meeting with Abbott personnel at MEDC to discuss mixing of Bt
	1830	Weather forecast from Dugway forecaster
	1900	Test team meeting and weather forecast at MEDC
15 June 73 Friday	0600	Calibration of helicopter at Johnson Flying Service
	0800	Met team sets at first 3 plots
	0900	Brief spray pilots at Johnson
	1330	Get forecast from Dugway
	1900	Test team meeting and weather forecast
16 June 73 Saturday	0430	Start wiresonde at Upper Sweeney Creek Take wiresonde every 30 minutes
	0500	Helicopter loaded and ready for spraying
	0510	Helicopter makes calibration spray run
	0515	Complete plot setup
	0530	Begin spray of first site
	1300	Met team sets up stations at second 2 sites
	1900	Test team meeting and weather forecast at MEDC
17 June 73 Sunday		Repeat previous day's spray schedule

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